(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 February 2004 (26.02.2004)

PCT

(10) International Publication Number
WO 2004/017547 A2

(51) International Patent Classification[7]: H04L

(21) International Application Number: PCT/IL2003/000682

(22) International Filing Date: 17 August 2003 (17.08.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/404,070	16 August 2002 (16.08.2002)	US
60/450,737	28 February 2003 (28.02.2003)	US
10/389,789	17 March 2003 (17.03.2003)	US
10/603,372	25 June 2003 (25.06.2003)	US

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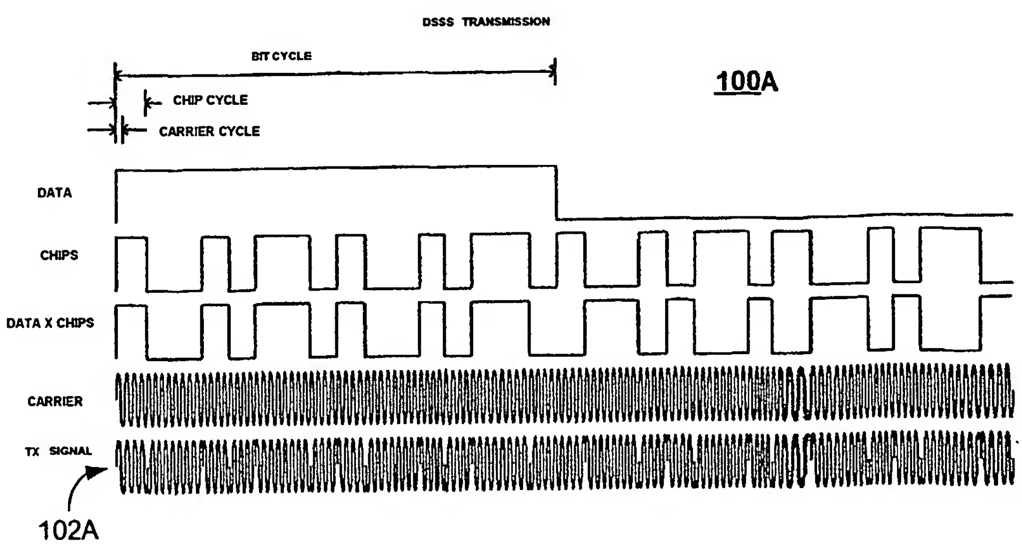
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: MULTI-BAND ULTRA-WIDE BAND COMMUNICATION METHOD AND SYSTEM



(57) Abstract: The present invention provides methods and systems for communication, including UWB based wireless and wired communication, in which information is transmitted utilizing a continuous series of burst symbol cycles, each burst symbol cycle including an ON period during which a number of chips representing a bit of information are transmitted using anultra-wide band signal, and an OFF period during which no signal is transmitted, providing advantages that can include scalability, adaptability and flexibility. Systems are provided that utilize the burst symbol cycle transmission technique in providing wireless and wired communication between multiple digital devices in a local area.

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MULTI-BAND ULTRA-WIDE BAND COMMUNICATION METHOD AND SYSTEM

RELATED PRIORITY APPLICATIONS

This application claims priority to U.S. Provisional Application No. 60/404,070 filed on August 16, 2002, and U.S. Provisional Application No. 60/450,737 filed on February 28, 2003, both of which applications are hereby incorporated herein by reference in their entirety. Additionally, this application claims priority to the following: U.S. Application No. 10/389,789 filed on March 17, 2003; U.S. Application No. 10/603,372, filed on June 25, 2003; U.S. Application No. _________, Attorney Docket No. 5579/4, filed on August 14, 2003, entitled, "System and Method for Multi-Band Ultra-wide Band Signal Generators"; and, U.S. Application No. __________, Attorney Docket No. 5579/5, entitled, "Scalable Ultra-Wide Band Communication System," filed on August 14, 2003 all of which applications are hereby incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

This invention relates in general to communication methods, systems, and apparatuses, and in particular to ultra-wide band based wireless communication methods, systems, and apparatuses.

The demand for short to medium range, high speed connectivity for multiple digital devices in a local environment continues to rise sharply. For example, many

workplaces and households today have many digital computing or entertainment devices such as desktop and laptop computers, television sets and other audio and video devices, DVD players, cameras, camcorders, projectors, handhelds, and others. Multiple computers and television sets, for instance, have become common in American households. In addition, the need for high speed connectivity with respect to such devices is becoming more and more important. These trends will inevitably increase even in the near future.

As the demand for high speed connectivity increases along with the number of digital devices in typical households and workplaces, the demand for wireless connectivity naturally grows commensurately. High-speed wiring running to many devices can be expensive, awkward, impractical and inconvenient. High speed wireless connectivity, on the other hand, offers many practical and aesthetic advantages, which accounts the great and increasing demand for it. Ideally, wireless connectivity in a local environment should provide high reliability, low cost, low interference caused by physical barriers such as walls or by co-existing wireless signals, security, and high speed data transfer for multiple digital devices. Existing narrowband wireless connectivity techniques do not provide such a solution, having problems such as high cost, unsatisfactory data transfer rates, unsatisfactory freedom from signal and obstacle related interference, unsatisfactory security, and other shortcomings. In fact, the state of the art does not provide a sufficiently satisfactory solution for providing high speed wireless connectivity for multiple digital devices in a local environment.

The state of the art in wireless connectivity generally includes utilization of spread spectrum systems for various applications. Spread spectrum techniques, which spread a signal over a broad range of frequencies, are known to provide high resistance against signal blocking, or "jamming," high security or resistance against "eavesdropping, " and high interference resistance. Spread Spectrum techniques have been used in systems in which

high security and freedom from tampering is required. Additionally, Code Division Multiple Access (CDMA), a spread spectrum, packet-based technique, is used in some cellular phone systems, providing increased capacity in part by allowing multiple simultaneous conversation signals to share the same frequencies at the same time.

Known spread spectrum and modulation techniques, including CDMA techniques, direct sequence spread spectrum (DSSS) techniques, time hopping spread spectrum (THSS) techniques, and pulse position modulation (PPM) techniques, do not satisfactorily provide wireless connectivity in a local environment, including high reliability, low cost, low interference, security, and high speed data transfer for multiple digital devices. In addition, known UWB transmission and communication methods and systems lack satisfactory quality in areas that can include flexibility, adaptivity and adaptive trade-off capabilities in areas such as power usage, range, and transfer rates, and low cost implementation.

A number of U.S. and non-U.S. patents and patent applications discuss spread spectrum or UWB related systems for various uses, but are nonetheless in accordance with the above described state of the art. The U.S. and non-U.S. patents and patent applications discussed below are hereby incorporated herein by reference in their entirety.

There are several Japanese patents and applications in some of these areas. Japanese patent application JP 11284599, filed on March 31, 1998 and published on October 15, 1999, discusses spread spectrum CDMA mobile communications. Japanese patent application JP 11313005, filed on April 27, 1998 and published on November 9, 1999, discusses a system for rapid carrier synchronization in spread spectrum communication using an intermittently operative signal demodulation circuit. Japanese patent application JP 11027180, filed on July 2, 1997 and published on January 29, 1999, and counterpart European application EP 0889600 discuss a receiving apparatus for use in a mobile

communications system, and particularly for use in spread spectrum Code Division Multiple Access communications between a base station and a mobile station. Japanese patent application JP 21378533, filed on November 18, 1988 and published on May 25, 1990, discusses a transmitter for spread spectrum communication.

A number of U.S. patents and published applications discuss spread spectrum or UWB in various contexts. U.S. Patent No. 6,026,125, issued February 15, 2000 to Larrick, Jr. et al., relates to utilization of a carrier-controlled pulsed UWB signal having a controlled center frequency and an adjustable bandwidth. U.S. Patent No. 6,351,652, issued February 6, 2002 to Finn et al., discusses impulse UWB communication. U.S. Patent No. 6,031,862, issued February 29, 2000 to Fullerton et al., and related patents including U.S. Patent Nos. 5,677,927, 5,960,031, 5,963,581, and 5,995,534, discuss a UWB communications system in which impulse derived signals are multiplied by a template signal, integrated, and then demodulated, to increase the usability if signals which would otherwise be obscured by noise. U.S. Patent No. 6,075,807, issued June 13, 2000 to Warren et al., relates to a spread spectrum digital matched filter. U.S. Patent No. 5,177,767, issued January 5, 1993 to Kato, discusses a "structurally simple" wireless spread spectrum transmitting or receiving apparatus which is described as eliminating the need for code synchronization. U.S. Patent No. 6,002,707, issued December 14, 1999 to Thue, relates to radar system using a wide frequency spectrum signal for radar transmission to eliminate the need for very high energy narrow pulse transmitter and receiver systems. U.S. Patent No. 5,347,537, issued June 21, 1994 to Mori, et al., and related patents including U.S. Patent Nos. 5,323,419 and 5,218,620, discuss a direct sequence spread spectrum transmitter and receiver system. U.S. Patent No. 5,206,881, issued April 27, 1993, discusses a spread spectrum communication system attempting to use rapid synchronization of pseudonoise code signals with data packet signals.

A number of published PCT international applications also discuss spread spectrum or UWB in various contexts. PCT international application, publication number WO 01/39451 published on May 31, 2001, discusses a waveform adaptive transmitter for use in radar or communications applications. PCT international application, publication number WO 01/93441, published on December 6, 2001, discusses a UWB high-speed digital communication system using wavelets or impulses. PCT international application, publication number WO 01/99300, published on December 27, 2001, discusses wireless communications using UWB signaling. PCT international application, publication number WO 01/11814, published on February 15, 2001, discusses a transmission method for broadband wired or wireless transmission of information using spread spectrum technology.

In accordance with all of the above, there is a need in the art for an improved communication methods and systems. Additionally, there is a need in the art for methods and systems to provide wireless connectivity between multiple digital devices in a local environment.

SUMMARY OF THE INVENTION

The present invention provides communication methods and systems. In some embodiments, the invention provides a method for transmitting information, including transmitting information as a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted. Bits of the information are mapped to symbols before the symbols are transmitted.

In another embodiment, the invention provides a method for receiving information, including receiving a continuous series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are received, each

symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is received. Symbols are mapped to bits of the information after the symbols are received.

In another embodiment, the invention provides a method for transmitting information, including translating a continuous signal stream into a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more bits of information is transmitted, and an OFF period during which no information is transmitted.

In other embodiments, the invention provides a method for transmitting information, including translating a narrowband signal into a wider band signal in which blocks of information from the narrowband signal are transmitted at a faster rate in the wider band signal than a transmission rate of the information in the narrowband signal. In one embodiment, blocks of information are transmitted in the wider band signal using a series of burst symbol cycles.

In other embodiments, the invention provides a method for transmitting information, including translating a narrowband signal into a wideband signal including a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more bits of information is transmitted, and an OFF period during which no information is transmitted. The wideband signal can be either carrier based or non-carrier based.

In another embodiment, the invention provides a method for transmitting information, including translating a continuous signal stream into a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted.

In some embodiments, the invention provides a method for wirelessly transmitting information, including transmitting information as a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted. Bits of the information are mapped to symbols before the symbols are transmitted.

In another embodiment, the invention provides a method for wirelessly receiving information, including receiving a continuous series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are received, each symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is received. Symbols are mapped to bits of the information after the symbols are received.

In another embodiment, the invention provides a method for wirelessly transmitting information, including translating a continuous signal stream into a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more bits of information is transmitted, and an OFF period during which no information is transmitted.

In another embodiment, the invention provides a method for wirelessly transmitting information, including translating a continuous signal stream into a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a bit sequence, each bit sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted.

In another embodiment, the invention provides a wideband based method for wirelessly transmitting information, including transmitting information as a series of burst

symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a chip sequence, each chip sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted. Bits of the information are mapped to symbols before the symbols are transmitted.

In another embodiment, the invention provides a wideband based method for wirelessly receiving information, including receiving a continuous series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are received, each symbol being a chip sequence, each chip sequence mapping to one or more bits of the information, and an OFF period during which no information is received. Symbols are mapped to bits of the information after the symbols are received.

In another embodiment, the invention provides a UWB based method for transmitting information, including transmitting information as a series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are transmitted, each symbol being a chip sequence, each chip sequence mapping to one or more bits of the information, and an OFF period during which no information is transmitted. Bits of the information are mapped to symbols before the symbols are transmitted.

In another embodiment, the invention provides a UWB based method for receiving information, including receiving a continuous series of burst symbol cycles. Each burst symbol cycle includes an ON period during which one or more symbols are received, each symbol being a chip sequence, each chip sequence mapping to one or more bits of the information, and an OFF period during which no information is received. Symbols are mapped to bits of the information after the symbols are received.

In some embodiments, the invention provides methods for UWB based communication in which information is transmitted utilizing a continuous series of burst

symbol cycles, each burst symbol cycle including an ON period during which a number of chips representing a bit of information are transmitted using an ultra-wide band signal, and an OFF period during which no signal is transmitted.

In some embodiments, the methods and systems utilize direct sequence spread spectrum (DSSS) transmission techniques to transmit the signal during the ON periods, and, in some embodiments, binary phase shift keying (BPSK) techniques are utilized to modulate a carrier signal to carry the information. In some embodiments, a duration of each ON and OFF period is varied to provide optimal performance based on variable parameters, such as range, transfer rate, or maximum power usage rate limitations or requirements.

In some embodiments, the methods and systems provide advantages that can include high data transfer rate capability, low power usage, security, low interference susceptibility, low cost implementation, flexibility, scalability, adaptability, and adaptive trade-off capabilities relating to parameters such as power usage, range, and transfer rates.

In some embodiments, the invention provides a system for UWB based, high data transfer rate wireless communication between digital devices, such as, for example, digital devices within a local area such as a home, a building or several buildings, and the system utilizing burst symbol cycle transmission techniques or modulation techniques as described above, or both. In some embodiments, the system further provides the advantages of modularity, auto-configuration, usability in various network topologies, and usability in a wide range of entertainment and computing applications that can require high data transfer rates.

In some embodiments, the techniques of the invention can be used effectively to facilitate communication between a network or group of many users (or communicating devices), and including many cells of users. For example, embodiments of the invention

including the use of time division multiplexing (TDM) can be used to facilitate synchronous and asynchronous communication between users or devices in a single cell. Additionally, in applications including communication between users or devices in different cells, some embodiments of the invention include the use of orthogonal or semi-orthogonal sequences to differentiate between users in different cells. Multiple user or multiple device embodiments of the invention, as described herein, generally can include multiple user and device embodiments.

In one embodiment, the invention provides an ultra-wide band based wireless communication method. The method includes, utilizing a transmitter, wirelessly transmitting the information. The method further includes, utilizing a receiver, receiving the transmitted information. Transmitting the information includes utilizing a series of burst symbol cycles, each burst symbol cycle including an ON period during which a plurality of chips are transmitted using an ultra-wide band signal, the plurality of chips being utilized to represent a bit of information, and an OFF period during which no signal is transmitted.

In another embodiment, the invention provides an ultra-wide band based wireless communication system. The system includes a transmitter for wirelessly transmitting the information. The system further includes a receiver for receiving the transmitted information. The transmitter transmits the information utilizing a series of burst symbol cycles, each burst symbol cycle including an ON period during which a plurality of chips are transmitted using an ultra-wide band signal, the plurality of chips being utilized to represent a bit of information, and an OFF period during which no signal is transmitted.

In another embodiment, the invention provides an ultra-wide band based wireless communication apparatus. The apparatus includes a transmitter for wirelessly transmitting the information. The apparatus further includes a receiver for receiving the transmitted information. The transmitter transmits the information utilizing a series of burst

symbol cycles, each burst symbol cycle including an ON period during which a plurality of chips are transmitted using an ultra-wide band signal, the plurality of chips being utilized to represent a bit of information, and an OFF period during which no signal is transmitted.

In another embodiment, the invention provides a system for ultra-wide band based wireless communication between digital devices. The system includes a first digital device comprising a transmitter and a receiver, and a second digital device including a transmitter and a receiver, in which the transmitters and the receivers of the digital devices are for facilitating wireless communication between the devices. The transmitters are for wirelessly transmitting information, and the receivers are for wirelessly receiving the transmitted information. The transmitters transmit the information utilizing a series of burst symbol cycles, each burst symbol cycle including an ON period during which a plurality of chips are transmitted using an ultra-wide band signal, the plurality of chips being utilized to represent a bit of information, and an OFF period during which no signal is transmitted.

In another embodiment, the invention provides an ultra-wide band based wireless communication method. The method includes, utilizing a transmitter, wirelessly transmitting the information. The method further includes, utilizing a receiver, receiving the transmitted information. Transmitting the information includes utilizing a series of burst symbol cycles, each burst symbol cycle including an ON period during which a plurality of bits are transmitted using an ultra-wide band signal, the plurality of bits being utilized to represent a bit of information, and an OFF period during which no signal is transmitted.

In another embodiment, the invention provides a method for transmitting information, including transmitting, for a first period of time of each of a series of burst symbol cycles, one or more symbols, in which each of the symbols includes a bit sequence, and in which each of the bit sequences maps to one or more bits of the information. The

method further includes suspending transmission for a second period of time of each of the series of burst symbol cycles.

In another embodiment, the invention provides a method for receiving information, including receiving, for a first period of time of each of a series of burst symbol cycles, one or more symbols, in which each of the symbols includes a bit sequence, and in which each of the bit sequences maps to one or more bits of the information. The method further includes suspending reception for a second period of time of each of the series of burst symbol cycles.

In another embodiment, the invention provides a method for transmitting information, including translating a continuous signal into a series of burst symbol cycles. The method further includes transmitting, for a first period of time of each of the series of burst symbol cycles, one or more symbols, in which each of the symbols includes a bit sequence, and in which each of the bit sequences maps to one or more bits of the information. The method further includes suspending transmission for a second period of time of each of the series of burst symbol cycles.

In another embodiment, the invention provides a method for transmitting information, including translating a narrowband signal containing the information into a second signal containing the information, the second signal being a wider band signal than the narrowband signal. The method further includes transmitting, for a first period of time of each of a series of cycles, one or more bits of the information at a faster rate than a rate at which the one or more bits information would be transmitted if the one or more bits of information were transmitted using the narrowband signal.

In another embodiment, the invention provides a method for transmitting information, including translating a continuous signal containing the information into a second signal containing the information, the second signal including a series of burst signal

cycles. The method further includes transmitting, for a first period of time of each of the series of burst symbol cycles, one or more symbols, each symbol including a bit sequence, in which each of the bit sequences maps to one or more bits of the information. The method further includes suspending transmission for a second period of time of each of the series of burst symbol cycles.

In another embodiment, the invention provides a method for transmitting information, including transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips. The method further includes suspending transmission for a second period of time of each of the series of burst symbol cycles.

In another embodiment, the invention provides an ultra-wide band based wireless communication system, the system including a transmitter for transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, one or more symbols, in which each of the symbols includes a bit sequence, and in which each of the bit sequences maps to one or more bits of the information. The transmitter is further for suspending transmission for a second period of time of each of the series of burst symbol cycles. The system further includes a receiver for receiving the transmitted symbols.

In another embodiment, the invention provides an ultra-wide band based wireless communication system, the system including a transmitter for transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips. The transmitter is further for suspending transmission for a second period of time of each of the series of burst symbol cycles. The system further includes a receiver for receiving the transmitted chips.

In another embodiment, the invention provides an ultra-wide band based

wireless communication apparatus, including a transmitter for transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips. The transmitter is further for suspending transmission for a second period of time of each of the series of burst symbol cycles. The apparatus further includes a receiver for receiving the transmitted chips.

In another embodiment, the invention provides a system for ultra-wide band based communication between digital devices, including a first digital device including a first transmitter and a first receiver. The system further includes a second digital device including a second transmitter and a second receiver. The first and the second transmitters and the first and the second receivers facilitate communication between the first and the second digital devices. The first and the second transmitters are for transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips. The first and the second transmitters are further for suspending transmission for a second period of time of each of the series of burst symbol cycles. The system further includes a receiver for receiving the transmitted chips..

In another embodiment, the invention provides a method for transmitting information, including means for transmitting, for a first period of time of each of a series of burst symbol cycles, one or more symbols, in which each of the symbols includes a bit sequence, and in which each of the bit sequences maps to one or more bits of the information. The method further includes means for suspending transmission for a second period of time of each of the series of burst symbol cycles.

The present invention further provides communication methods and systems, including multi-band ultra-wide band communication methods and systems. In some embodiments, methods and systems are provided in which frequency sub-bands of an ultra-wide band spectrum are allocated or signal transmission. An ultra-wide band transmission

including the information is sent, including sending a signal over each of the plurality of sub-bands.

In some embodiments, methods are provided in which a first data signal containing information is converted into an encoded signal using an Inverse Fast Fourier transform. The encoded signal is converted into an encoded pulsed ultra-wide band signal that can be pulsed or transmitted using burst symbol cycles. The encoded pulsed ultra-wide band signal is decoded using a Fast Fourier Transform to obtain the information.

In some embodiments, the invention provides a method for transmitting information, including allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum. The method further includes sending an ultra-wide band transmission including the information over the ultra-wide band spectrum, including sending a signal over each of the plurality of sub-bands.

In another embodiment, the invention provides a method for receiving information including allocating, for signal reception, each of a plurality of frequency sub-bands of an ultra-wide band spectrum. The method further includes receiving an ultra-wide band transmission including the information over the ultra-wide band spectrum, including receiving a signal over each of the plurality of sub-bands.

In another embodiment, the invention provides a method for communicating information, including allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum. The method further includes sending an ultra-wide band transmission including the information over the ultra-wide band spectrum, including sending a signal over each of the plurality of sub-bands. The method further includes receiving the ultra-wide band transmission including the information over the ultra-wide band spectrum, including receiving the signals.

In another embodiment, the invention provides a system for communicating information, including allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum. The system further includes a transmitter for sending an ultra-wide band transmission including the information over the ultra-wide band spectrum, including sending a signal over each of the plurality of sub-bands. The system further includes a receiver for receiving the ultra-wide band transmission including the information over the ultra-wide band spectrum, including receiving the signals.

In another embodiment, the invention provides a method for communicating information, including converting a first data signal containing information into an encoded signal using an Inverse Fast Fourier Transform. The method further includes converting the encoded signal into an encoded ultra-wide band signal including burst symbol cycles. The method further includes decoding the encoded ultra-wide band signal using a Fast Fourier Transform to obtain the information.

In another embodiment, the invention provides a method for communicating information, including converting a first data signal containing information into an encoded signal using an Inverse Fast Fourier Transform. The method further includes converting the encoded signal into an encoded pulsed ultra-wide band signal. The method further includes decoding the encoded pulsed ultra-wide band signal using a Fast Fourier Transform to obtain the information.

In another embodiment, the invention provides a method for transmitting information, including, after modulation of a narrowband signal, translating the narrowband signal containing the information into a second signal containing the information, the second signal being a wider band signal than the narrowband signal, and the narrowband signal and the second signal including the same modulated waveform.

In another embodiment, the invention provides a method for transmitting information, including transmitting, for a first period of time of each of a series of cycles, one or more bits of the information at a faster rate than a rate at which the one or more bits information would be transmitted if the one or more bits of information were transmitted using the narrowband signal.

In one embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission comprising the information by transmitting a burst symbol cycle signal over each of the plurality of frequency sub-bands.

In another embodiment, the invention provides a fast switching frequency generator for facilitating generation of a multi-band ultra-wide band transmission, the generator including a circuit. The circuit includes at least one voltage controlled oscillator and at least one divider. The at least one voltage controlled oscillator is adapted for use in generating a signal of a particular center frequency. The at least one divider is adapted for use in facilitating generation of multiple transmission frequency bands of the multi-band ultra-wide band transmission by outputting, from an input signal of a particular center frequency, signals of different frequency multiples of a step frequency.

In another embodiment, the invention provides a method for facilitating transmission of information using ultra-wide band transmission. The method includes generating a first digital signal for use in an ultra-wide band transmission. The method further includes substantially removing at least one harmonic from the first digital signal by subtracting, from the first digital signal, a second digital signal that is a delayed form of the first digital signal, to produce a third digital signal that is of substantially the same frequency

as the first digital signal but that substantially does not include at least one harmonic included in the first digital signal.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands. Phase continuity is maintained by dividing each of the frequency sub-bands into a plurality of segments, and cycling transmission between segments of each of the sub-bands.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands, including producing at least one analog carrier wave of a frequency sub-band using outputs from a plurality of digital to analog converters.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands, including using a sine wave envelope to reduce side lobes in at least one carrier frequency, including multiplying a signal by a sine wave of a lower frequency than the carrier frequency.

In another embodiment, the invention provides a method for facilitating transmission of information using ultra-wide band transmission. The method includes

generating at least one carrier wave for use in an ultra-wide band transmission. The method further includes isolating a single monocycle from the carrier wave by producing a first signal that is a delayed form of the carrier wave and combining the carrier wave with the first signal to isolate a single monocycle.

In another embodiment, the invention provides a method for facilitating transmission of information using ultra-wide band transmission. The method includes generating a narrow-band pulse signal for use in an ultra-wide band transmission, including generating a first pulse signal; producing a second pulse signal that is a delayed form of the first pulse signal; and, using a differential amplifier, subtracting the first pulse signal from the second pulse signal to produce the narrow-band pulse signal.

In another embodiment, the invention provides a method for facilitating transmission of information. The method includes generating an ultra-wide band signal, including: generating a first ultra-wide band carrier signal; combining the first carrier signal with a sine wave envelope to generate a first combined signal with reduced side lobes relative to the first carrier signal; combining the first combined signal with an information signal to generate a second combined signal; and transmitting the second combined signal as at least part of a multi-band ultra-wide band transmission.

In another embodiment, the invention provides a method for facilitating transmission of information. The method includes generating an ultra-wide band signal, including combining an information signal with a sine wave envelope to generate a first combined signal; combining the first combined signal with a generated carrier signal to generate a second combined signal with reduced side lobes relative to the generated carrier signal; and transmitting the second combined signal as at least part of a multi-band ultra-wide band transmission.

In one embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes allowing variation of at least one transmission parameter to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a method for receiving information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes receiving an ultra-wide band transmission including the information by receiving signals transmitted over each of the plurality of frequency sub-bands. The method further includes allowing variation of at least one of one or more reception parameters to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a method for communicating information using ultra-wide band transmission and reception. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes receiving an ultra-wide band transmission including the information by receiving signals transmitted over each of the plurality of frequency sub-bands. The method further includes allowing variation of at least one of one or more transmission parameters and one or

more reception parameters to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes setting at least one transmission parameter to facilitate a desired trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes varying pulse repetition frequency to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission, the method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The invention further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes setting pulse repetition frequency to mitigate inter-symbol interference.

In another embodiment, the invention provides a method for transmitting information using ultra-wide band transmission. The method includes allocating, for signal transmission, each of a plurality of frequency sub-bands. The method further includes sending an ultra-wide band transmission including the information by transmitting a signal over each of the plurality of frequency sub-bands. The method further includes allowing variation of pulse repetition frequency to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, and resistance to multipath interference and spectral flatness.

In another embodiment, the invention provides a system for communicating information using ultra-wide band transmission and reception. The system includes a transmitter for sending an ultra-wide band transmission including the information by transmitting a signal over each of a plurality of frequency sub-bands. The system further includes a receiver for receiving an ultra-wide band transmission including the information by receiving signals transmitted over each of a plurality of frequency sub-bands. The system allows for at least one of selection of and variation of at least one of one or more transmission parameters and one or more reception parameters to provide adaptive trade-off between at least two of power consumption, bit rate, performance, range, and resistance to multipath interference and spectral flatness.

Additional aspects of the present invention will be apparent in view of the description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the figures of the accompanying drawings which are meant to be exemplary and not limiting, in which like references are intended to refer to like or corresponding parts, and in which:

FIG. 1 is a timing diagram that depicts characteristics of a prior art direct sequence spread spectrum transmission technique;

FIG. 2 is a timing diagram that depicts characteristics of a prior art pulse position modulation spread spectrum transmission technique;

FIG. 3 is a timing diagram that depicts characteristics of a burst symbol cycle based transmission, according to one embodiment of the invention;

FIG. 4 is a block diagram that depicts a system that utilizes burst symbol cycle transmission and reception, according to one embodiment of the invention;

FIG. 5 is a block diagram that depicts a system that utilizes burst symbol cycle

bit

cycle transmission and reception between two digital devices, according to one embodiment of the invention;

FIG. 6 is a block diagram that depicts a wireless Local area network (LAN) implemented utilizing a gateway server and connecting multiple digital devices, according to one embodiment of the invention;

FIG. 7 is a block diagram depicting an implementation of a transmitter that

can

transmit burst symbol cycles, according to one embodiment of the invention;

FIG. 8 is a block diagram depicting a shift register based implementation of parallel loading for generating burst symbol cycles, which can be utilized in the transmitter depicted in FIG. 7, according to one embodiment of the invention;

FIG. 9 is a block diagram depicting a multiplexer based implementation of parallel loading for generating burst symbol cycles, which can be utilized in the transmitter depicted in FIG. 7, according to one embodiment of the invention;

FIG. 10 is a block diagram of an implementation of a receiver that can receive burst symbol cycles transmissions, according to one embodiment of the invention;

FIG. 11 is a timing diagram that depicts characteristics of a burst symbol cycle reception, according to one embodiment of the invention;

FIG. 12 is a state diagram depicting states associated with signal acquisition and tracking by a receiver, according to one embodiment of the invention;

FIG. 13 is a conceptual diagram graphically depicting $I^2 + Q^2$ correlation as performed at state 3 1206 of FIG. 12, according to one embodiment of the invention;

FIG. 14 is a timing diagram that depicts characteristics of packet transmission with non-burst symbol cycle preamble transmission, according to one embodiment of the invention;

FIG. 15 is a flow diagram depicting a method of transmission, according to one embodiment of the invention;

FIG. 16 is a flow diagram depicting a method of reception, according to one embodiment of the invention;

FIG. 17 is a flow diagram depicting a method of burst symbol cycle signal acquisition and tracking by a receiver, according to one embodiment of the invention;

FIG. 17A is a graph depicting a spectrum of a signal in which each burst is transmitted using a different frequency;

FIG. 18 is a block diagram depicting an implementation of a transceiver, according to one embodiment of the invention;

FIG. 19 is a schematic diagram depicting an implementation of a transceiver, according to one embodiment of the invention;

FIG. 20 is a schematic diagram depicting another implementation of a transceiver, according to another embodiment of the invention;

FIG. 21 is a block diagram that depicts a home gateway server connected to multiple digital devices, according to one embodiment of the invention;

FIG. 22 is a block diagram that depicts an audio/video server connected to multiple audio/video digital devices, according to one embodiment of the invention;

FIG. 23 is a block diagram that depicts multiple digital devices, each connected to a projector, according to one embodiment of the invention;

FIG. 24 is a block diagram that depicts a DVD player connected to multiple television sets, according to one embodiment of the invention;

FIG. 25 is a block diagram that depicts a diagram of an in-building wireless network topology, according to one embodiment of the invention; and,

FIG. 26 is a block diagram that depicts a network including a home gateway and multiple digital devices within a house, according to one embodiment of the invention.

FIG. 27 is a frequency vs. power spectrum magnitude chart of a multi-band UWB implementation, according to one embodiment of the invention;

FIG. 28 is a table depicting time-frequency interleaving sequences, according to one embodiment of the invention;

FIG. 29 is a block diagram depicting an implementation of a multi-band signal generator, according to one embodiment of the invention;

FIG. 30 is a timing diagram that depicts a burst transmission, according to one embodiment of the invention;

FIG. 31 is a timing diagram that depicts a symbol mapped transmission, according to one embodiment of the invention;

FIG. 32 is a timing diagram that depicts a pulsed OFDM transmission, according to one embodiment of the invention;

FIG. 33 is a timing diagram that depicts a burst OFDM transmission, according to one embodiment of the invention;

FIG. 34 is a block diagram depicting an implementation of a multi-pulsed OFDM, according to one embodiment of the invention;

FIG. 35 is a block diagram depicting one implementation of an OFDM transmitter and receiver mechanism, according to one embodiment of the invention;

FIG. 36 is a block diagram depicting an OFDM transmitter and receiver mechanism, according to one embodiment of the invention;

FIG. 37 is a chart depicting a frequency selection option implementation, according to one embodiment of the invention;

FIG. 38 is a timing diagram depicting an elongated sample window implementation, according to one embodiment of the invention;

FIG. 39 is a block diagram depicting an implementation of multiple transmission schemes, according to one embodiment of the invention; and

FIG. 40 is a timing diagram depicting multiple transmission schemes, according to one embodiment of the invention.

FIG. 41 is a block diagram depicting multiple generators combined to generate one or more of the sub-bands in a multi-band UWB system, according to one embodiment of the invention;

FIG. 42 is a circuit diagram relating to a fast switching frequency generator, according to one embodiment of the invention;

FIG. 43 is a timing diagram that depicts a technique for digitally removing harmonics, according to one embodiment of the invention;

FIG.44 is a chart depicting a technique for dividing each carrier signal into 4 equal length segments, according to one embodiment of the invention;

FIG. 45 is a circuit diagram relating to a method for generating sub-band carrier waves using digital to analog converters (D/A) and shift registers, according to one embodiment of the invention;

FIG. 46 is a circuit diagram relating to a circuit that can be used to multiply a carrier signal by an envelope, according to one embodiment of the invention;

FIG. 47A is a graph of the time domain and of a signal with an envelope, according to one embodiment of the invention;

FIG. 47B is a graph of the frequency domain and of a signal with an envelope, according to one embodiment of the invention;

FIG. 48 is a timing diagram depicting a single monocycle extracted from a carrier wave, according to one embodiment of the invention;

FIG. 49 is a timing diagram depicting a technique for isolating the monocycle from among a group of cycles, according to one embodiment of the invention;

FIG. 50 is a circuit diagram illustrating a technique for carrier switching, according to one embodiment of the invention;

FIG. 51 is a circuit diagram illustrating another technique for carrier switching, according to one embodiment of the invention;

FIG. 52 is a timing diagram illustrating isolation of a single monocycle using the technique illustrated with reference to FIG. 11, according to one embodiment of the invention;

FIG. 53 is a circuit diagram illustrating a technique for isolating a single monocycle using a stub, according to one embodiment of the invention;

FIG. 54 is a timing diagram illustrating isolation of a single monocycle using the technique illustrated with reference to FIG. 13, according to one embodiment of the invention;

FIG. 55 is a circuit diagram relating to a carrierless transmitter, according to one embodiment of the invention;

FIG. 56 is a timing diagram illustrating resultant signals associated with the carrierless transmitter illustrated with reference to FIG. 15, according to one embodiment of the invention;

FIG. 57 is a circuit diagram illustrating a pulse generating transmitter, according to one embodiment of the invention;

FIG. 58 is a timing diagram illustrating resultant signals at different stages of various ternary modulation schemes, according to one embodiment of the invention; and

FIG. 59 is a circuit diagram relating to a technique for increasing the frequency of a data clock.

FIG. 60 is a timing diagram of signals transmitted using various levels of PRF reduction;

FIG. 61 is a timing diagram showing energy collection by a receiver;

FIG. 62 is a timing diagram showing inter-symbol interference in transmitted signals;

FIG. 63 is a timing diagram showing multiple access interference in transmitted signals;

FIG. 64 is a timing diagram showing multiple access interference in transmitted signals;

FIG. 65 is a timing diagram showing possible collisions between two signals;

FIG. 66 is a timing diagram showing possible collisions between two signals;

FIG. 67 is a chart of frequency hopping sequences for avoiding collisions on multiple pico-nets;

FIG. 68 is a chart of frequency hopping sequences for sequences for avoiding collisions on multiple pico-nets using half and one-third PRF;

FIG. 69 is a chart showing frequency hopping sequences sequences for avoiding collisions on multiple pico-nets using reduced PRF;

FIG. 70 is a chart showing two fr4quency hopping sequences that may be transmitted in parallel;

FIG. 71 is a graph showing signals transmitted using cyclic prefix;

FIG. 72 is a graph showing signals transmitted using zero padding; and

FIG. 73 is a graph showing signals transmitted using cyclic prefix and zero padding.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description of the preferred embodiment, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

FIGs. 1 and 2 are timing diagrams that depict examples of existing transmission techniques that can be used in spread spectrum techniques. Specifically, FIG. 1 is a timing diagram that depicts characteristics 100A of an existing direct sequence spread spectrum (DSSS) transmission technique utilizing a binary phase shift keying modulation technique, and FIG. 2 is a timing diagram that depicts characteristics 200A of an existing pulse position transmission technique.

In FIG. 1, as shown by the transmitted signal, or TX signal 102A, the DSSS transmission techniques utilize continuous transmission of BPSK modulated signal. As with spread spectrum systems generally, each bit of information is represented by a number of

transmitted chips. It is to be noted that, in the usual computer parlance, a bit is the smallest unit of information, and a binary bit is usually represented as a "0" or a "1". In this usual computer parlance, a chip is in fact a bit. Typically in spread spectrum system parlance, however, the term "bit" is utilized to mean a bit of information before spreading, and the term "chip" is typically utilized to mean a bit of information after spreading, which is utilized in combination with other chips to represent a single bit of information existing prior to spreading.

FIG. 2 depicts characteristics 200A of a prior art pulse transmission, including transmitted signal, or TX signal 202A. As depicted in transmitted signal 202A, the signal consists of intermittent pulses 204AA, 204BA, each of the pulses 204AA, 204BA being used to transmit one or more bits of information (the term "bit" as used in this paragraph having a meaning in accordance with typical computer parlance, meaning any smallest unit of information). Pulse transmission techniques, in which intermittent single bits are transmitted, can be used in spread spectrum as well as non-spread spectrum techniques, and with modulation techniques such as pulse amplitude modulation, pulse position modulation (PPM), or other pulse timing based modulation..

FIG. 3 is a timing diagram that depicts characteristics 300A of a burst symbol cycle based transmission 304A, according to one embodiment of the invention. A burst symbol cycle based transmission 304A is depicted. Each burst symbol cycle includes an ON period during which a number of chips representing a bit of information are transmitted using an ultra-wide band signal, and an OFF period during which no signal is transmitted. In this embodiment, each burst symbol cycle is used to transmit a number of chips which represent a bit. As depicted, burst symbol cycle 302A includes ON period 308 followed by OFF period 310A. As depicted, each ON period transmission 306AA, 306BA contains a number of consecutive, uninterrupted transmitted chips 306A. In the embodiment depicted, binary

phase shift keying (BPSK) is used to modulate the transmitted signal 304A to carry the chips. In other embodiments of the invention, however, many other forms of modulation can be utilized, including other phase modulation techniques such as quaternary phase shift keying (QPSK), position based modulation, combinations of phase and position based modulation, and various other modulation techniques, including various modulation techniques typically associated with narrow band transmission systems. For example, in some embodiments, narrowband signals are translated into a series of burst symbol cycles and can be transformed into a UWB signal, which techniques can include multiplication of the narrowband signal by a wideband burst symbol cycle signal (which can be either a carrier based or non-carrier based signal, as further described in Appendix C of previously incorporated by reference U.S. Provisional Patent Application No. 60/404,070), or even a general wavelet.

In some embodiments of the invention, information to be transmitted is translated into a symbol, the symbol being a sequence of bits that maps to, or is used to represent, one or more bits of information to be transmitted. The bit sequence is generally different than the one or more bits of information, but, in some embodiments, can be identical. In addition, in some embodiments, in which the bit sequence is identical to the one or more bits of information to be transmitted, mapping can be unnecessary (both on a transmitting and receiving end), and therefore not included. As such, in some embodiments, the term "symbol" can simply include signals or bits of information to be transmitted or received.

Generally, however, bits of information are mapped to one or more symbols, and the symbols are transmitted during an ON period. On a receiving end, the one or more symbols are received during an ON period, and then mapped, or decoded, to the one or more bits of information the symbols are used to represent. Although generally a symbol maps to

one or more bits of information, it is to be noted that, in some embodiments of the invention, more than one symbol or burst can be used to represent a single bit of information.

In some embodiments, the bit sequences of the symbols can be chosen or varied to control or create trade-offs between system parameters. For example, peak to average power ratio and spectral shaping or widening can be controlled by such techniques. It is to be noted that, in some embodiments of the invention, sequences do not have to be repeated or constant, but can change between, for example, bits or groups of bits, packets, or cells. It is to be noted, however, that, in some embodiments of the invention, other techniques besides sequencing related techniques can be used to control various system parameters. For example, see discussion herein of embodiments of the invention using orthogonal frequency division multiplexing, or OFDM. Furthermore, in some embodiments, each burst can be transmitted using a different frequency or frequency range, or in more than one frequency or frequency range, or in different positions. For example, see discussion herein of embodiments of the invention using two-plane transmitting.

In addition, in some embodiments of the invention, lengths of ON periods and lengths of OFF periods change from cycle to cycle.

In general, burst symbol cycle transmission, according to various embodiments of the invention, provide greater flexibility and control of system parameters, including bit rates, and duty cycles. For example, pulse transmission generally uses either pulse position modulation or pulse amplitude modulation. The relatively simple pulse transmission techniques do not allow the degree of control over system parameters as do the techniques of the present invention. In addition, various narrowband and spread spectrum techniques also do not allow such control. For example, spread spectrum DSSS techniques generally provide lower peak power than, for example, pulse transmission techniques, but higher overall power consumption. Pulse transmission techniques, conversely, provide lower

overall power consumption than DSSS techniques, but higher peak power. In addition, in some embodiments of the invention, spectral shaping is controlled by selecting polarity of signals of an ON period of a burst symbol cycle, which is an advantage over pulse transmission techniques, which have a constant spectral shape that cannot be controlled in the manner just described. In addition, some embodiments of the present invention provide advantageous trade off control capability, in comparison with DSSS techniques and pulse techniques, with respect to other parameters, including, for example, filtering, switching. Various embodiments of the present invention, however, allow trade off and control between such parameters, which degree of control is unavailable in existing techniques.

In some embodiments, a continuous or other non-burst symbol cycle data stream or signal is translated into burst symbol cycles before being transmitted. For example, various narrowband transmissions can be converted into wideband burst symbol cycle signals according to the methods of the present invention. By such techniques, the advantages of transmission and reception according to some embodiments of the present invention can be gained, which advantages would be unavailable if information is transmitted and received by existing narrowband techniques. As described in more detail herein, some embodiments of the invention include translating a narrowband signal into a series of burst symbol cycles by multiplying the continuous signal by a burst symbol cycle signal (which can be either a carrier based or non-carrier based signal, or a as further described in Appendix C of previously incorporated by reference U.S. Provisional Patent Application No. 60/404,070), or even a general wavelet. Such techniques can be used, in some embodiments of the invention, to translate a narrowband signal into a wideband or a UWB signal.

In some embodiments of the invention, blocks of a narrowband signal are transmitted at a faster rate than in the original narrowband signal, thus widening the spectrum of the signal, without multiplication by a wider band signal.

In some embodiments of the invention in which information is transmitted (or received) at a faster rate than in an original narrowband signal, blocks of information can be transmitted (or received) in the form of burst symbol cycles including an ON period during which the information of the block is transmitted, followed by an OFF period to fill the remainder of time that would be required for the block of information to be transmitted in the original narrowband signal. Alternatively, a portion of the remainder of time can be used to transmit signal, such as a repeated block or blocks of information, a different block or blocks of information, a partial block or blocks of information, or a varied form of block or blocks of information, such that the OFF period of each cycle is of shorter duration. Furthermore, in some embodiments, the entire remainder period can be used to transmit signal, such that instead of a series of burst symbol cycles, a continuous signal is transmitted.

It is to be noted that the methods of the invention can be used to advantage in wired as well as wireless systems, including wired UWB systems and implementations. It is to be noted, however, that the methods of the invention include embodiments in which no narrowband or other continuous or non-continuous data stream is converted. It is further to be noted that the invention contemplated embodiments including a carrier signal as well as embodiments that do not include a carrier signal (see Appendix C of previously incorporated by reference U.S. Provisional Patent Application No. 60/404,070 for further discussion and examples of carrier and non-carrier based embodiments of the invention).

It is to be noted that, generally, burst symbol cycle transmission causes a wider spectral band than continuous or other non-burst symbol cycle transmissions. For example, translating narrowband data streams into burst symbol cycles generally causes widening of the spectrum utilized. As such, although the techniques of various embodiments of the invention can be applied and are useful in non-UWB contexts, the techniques are generally especially advantageous when utilized for wireless UWB communication, since,

among other things, the techniques generally lend themselves best to very wide band communication systems, and also help widen the used spectral bandwidth.

In the embodiment depicted in FIG 3, burst symbol cycle transmission is utilized in a spread spectrum context. As used herein, the term, "spread spectrum" is not limited to existing spread spectrum techniques, but rather includes any technique, including new techniques as described herein, in which some or several aspects of spread spectrum methodology is a part. In some embodiments, such as the spread spectrum based embodiment depicted in FIG. 3, power control can be implemented by, for example, changing the number of chips per bit.

To support and enable transmissions to multiple different receiving entities, such as, for example, digital or computerized devices, and different chip polarity patterns and sequence positions can be utilized for identification of certain transmitted information as being intended for a particular receiving entity or entities. Such techniques can be utilized to facilitate communication between many users or devices, including multiple cells of users or devices, each cell containing multiple users or devices. Sequences can be the same for all transmitted bits for an intended receiving entity, or can change every bit. Sequences that can be so utilized include, for example, pseudonoise (PN) sequences, Barker sequences, Gold sequences, Kasami sequences, or others.

UWB transmission systems have various uses. UWB transmission systems are typically within the 0 MHz to 5 GHz band, typically cover a large spectrum of above 20% of the center frequency, and typically radiate a power of approximately 1 mW. UWB systems have in the past been used by for radar and radar-like applications, allowing penetration of thick obstacles such as building walls. UWB is also known to provide high resistance against detection and interception, high multipath immunity, high throughput, and

precision ranging and localization. Decreased restriction on the use of UWB is expected in the near future.

The present invention provides UWB based communication methods and systems. In some embodiments, the invention provides methods for UWB based communication in which information is transmitted as described with reference to FIG. 3, utilizing a continuous series of burst symbol cycles, each burst symbol cycle including an ON period during which a number of chips representing a bit of information are transmitted using an ultra-wide band signal, and an OFF period during which no signal is transmitted. In some embodiments, narrowband signals are translated into a series of wider band or wide band burst symbol cycles, or are transformed into a UWB signal, and techniques used can include multiplication of the narrowband signal by a burst symbol cycle signal (which can be either a carrier based or non-carrier based signal, or a as further described in Appendix C of previously incorporated by reference U.S. Provisional Patent Application No. 60/404,070), or even a general wavelet. In some embodiments, a duration of each ON and OFF period is varied, such as by using a fast variable ON period, to provide optimal performance based on variable parameters, such as range, transfer rate, or maximum power usage rate limitations or requirements. In some embodiments, the methods and systems provide advantages that can include high data transfer rate capability, low power usage, security, low interference susceptibility, low cost implementation, flexibility, adaptability, and adaptive trade-off capabilities relating to parameters such as power usage, range, and transfer rates.

In some embodiments, the invention provides a system for UWB based, high data transfer rate wireless communication between digital devices, such as, for example, digital devices within a local area such as a home, a building or several buildings, and the system utilizing burst symbol cycle transmission techniques or modulation techniques as described above, or both. In some embodiments, the system further provides the advantages

of modularity, auto-configuration, usability in various network topologies, and usability in a wide range of entertainment and computing applications that can require high data transfer rates, including multi-streaming of high quality audio and video, and broadband multimedia applications.

In some embodiments, the physical components, hardware, software, and programs as described herein are implemented utilizing small, low power modular subunits including PHY, MAC, and protocol stack software. In some embodiments, the subunits connect to digital or computerized devices utilizing standard interfaces, such as USB, IEEE 1394, Ethernet, PCMCIA, etc. In some embodiments, auto-configuration is provided, and power can be supplied from standard interfaces. In some embodiments, subunits or other components are mounted on an antenna.

In some embodiments, the methods and systems of the invention are utilized to support a wide range of simultaneously provided wireless services and applications, providing high data transfer rates and a high degree of reliability and quality. For example, supported applications can include high rate distribution of MPEG-2 channels, high quality broadband and multimedia applications. Various low to medium transfer rate applications can also be supported, including bi-directional real-time channels for video or audio calling or conferencing, or interactive gaming, resource file sharing, file transfer, and control information transfer. In some embodiments, 100-500MB/sec or greater maximum transfer rates can be achieved. In some embodiments, higher or middle rate services can be supported for ranges up to about 15-20 meters, and middle or lower rate services for ranges of about 30-50 meters or more. In some embodiments, the invention supports up to at least three independent cells with overlap in a typical building, and supports non-interfering co-existence with other wireless systems in typical environments and use conditions.

FIGs. 4-6 are block diagrams that illustrate certain implementations and embodiments of the invention. FIG. 4 depicts a system 400A that utilizes burst symbol cycle transmission and reception, according to one embodiment of the invention. Herein, a burst symbol cycle transmission generally includes a transmission including a continuous series of burst symbol cycles. As depicted, a burst symbol cycle transmission 402A is wirelessly transmitted from a transmitter 404A and received by a receiver 406A. Herein, wireless transmissions and wireless communications refer to transmissions and communications that are sent wirelessly from a transmitting entity to a receiving entity; the terms generally do not refer to internal workings of transmitters, receivers, and transceivers, which can involve wires.

Herein, the terms transmitter, receiver, and transceiver generally include devices that include any and all necessary components necessary to implement the functions of the device, including physical components, such as one or more antennas, as well as computerized or computer hardware, software, and programming. The transmitter 404A and receiver 406A each include one or more antennas 426A, 428A for transmitting and receiving burst symbol cycle transmissions in accordance with the invention. The transmitter 404A and receiver 406A each include one or more central processing units (CPUs) 408A, 416A, and one or more data storage devices 410A, 418A. The data storage device of the transmitter 404A includes a digital information database 414A and a transmitter program 412A. The data storage device of the receiver 406A includes a digital information database 422A and a receiver program 412A. Data storage devices as described herein can include various amounts of RAM for storing computer programs and other data. In addition, transmitters, receivers, and transceivers as described herein can include various other components typically associated with transmitters, receivers, and transceivers. In different embodiments, transmitters, receivers, and transceivers as described herein can include special or limited

purpose computers, or can include general purpose computers that generally operate under and execute computer programs under the control of an operating system, such as Windows, Macintosh, UNIX, etc. Furthermore, transceivers, as described herein, generally includes a device having the functionality of a transmitter and a receiver as described herein, and any such device is considered to include a transmitter and receiver, whether or not physical or any computerized or programming components of the transmitter and receiver are separate or indistinguishably intermingled.

The transmitter program 412A and the receiver program 416A each generally include all programming and applications, programming or application modules, etc. necessary to implement transmission and reception of burst symbol cycle transmissions, respectively, in accordance with the methods of the invention as described herein. In some embodiments, the transmitter 404A, the receiver 406A, or each, can be replaced with a transceiver, combining the functionality of both a transmitter and a receiver.

Generally, the computer programs of the present invention are tangibly embodied in a computer-readable medium, e.g., one or more data storage devices attached to a computer. In some embodiments under the control of an operating system, computer programs may be loaded from data storage devices into computer RAM for subsequent execution by the CPU. The computer programs include instructions which, when read and executed by the computer, cause the computer to perform the steps necessary to execute elements of techniques described herein.

The digital information databases 414A, 422A of the transmitter 404A and the receiver 422A generally include any and all stored information utilized in the functions of the transmitter 404A and the receiver 406A. For example, the digital information database 414Å of the transmitter 404A includes stored information to be transmitted to the receiver, as well as any and all stored intermediate, processed, coded, and decoded information, in accordance

with the methods of the invention as described herein. The digital information database 422A of the receiver 406A generally include any and all received information, as well as any and all intermediate, processed, coded, and decoded information, in accordance with the methods of the invention as described herein. While not shown, in some embodiments, the transmitter 404A, as well as transceivers described herein, can obtain or receive information to be stored in the digital information database 414A from various sources and in various ways, such as by wired communication, wireless communication, reading of an external storage device such as a floppy disk or compact disk, or in any of various other ways.

FIG. 5 depicts a system 500A that utilizes burst symbol cycle transmission 506 transmitted by a transmitter 506A of a first digital device 502A and received by a receiver 508A of a second digital device 504A. As depicted, the transceiver 522A includes a transmitter 510A, a receivers 512A, one or more CPUs 514A, and one or more data storage devices 516A. The data storage device 516A includes a transceiver program and a digital information database 520A. It is to be understood that the transceiver 522A generally includes any and all components necessary to allow transmission and reception of burst symbol cycle transmissions in accordance with the invention as described herein. Various different configurations are possible in accordance with the invention. For example, the transmitter 510A and receiver 512A and elements thereof can be separate, as shown, or combined, and CPUs and data storage devices can be included in the transmitter as well as in the receiver, or one or more CPUs, data storage devices, and other elements can be utilized to perform transmitter and receiver functions. As depicted, the data storage device 516A of the transceiver 522A includes transceiver program 518A and digital information database 520A, which, alone or in combination with elements of the transmitter 510A and the receiver 512A, enable to transceiver to perform burst symbol cycle transmission and reception in accordance with the methods of the invention as described herein.

FIG. 6 depicts a wireless Local area network (LAN) 602 implemented utilizing a gateway server 604A and connecting multiple digital devices 616AA, 616BA, 616CA according to one embodiment of the invention. It is to be noted that, in some embodiments, the invention can be implemented, in a wireless or wired fashion, within or including a personal area network (PAN), or a LAN, or both, or various other types and combinations of networks. The gateway server 604A is a server computer including a CPU 606A, a transceiver 608A, and a data storage device 610A. As depicted, the data storage device includes a digital information database 612A and a home gateway program 614A. The gateway server 604A can be an audio/video server or any of various types of servers for various applications. The gateway program 614A generally includes all programming, applications, and programming or application modules necessary to perform the functions of the gateway server 604A as described herein. Specifically, the gateway server 604A is for transmission and reception of burst symbol cycle transmissions as well as management and integration of communication through the wireless LAN 602A to, from, and between the digital devices and the gateway server 604A. As depicted, the gateway server 604A coordinates and manages information flow, which can include multiple simultaneous transmissions from transmitting devices intended to be received by one or more particular receiving devices. Arrows 618AA, 618BA, 618CA, and 618DA represent burst symbol cycle communications.

FIG. 7 is a block diagram 700A depicting an implementation of a transmitter that can transmit burst symbol cycles, according to one embodiment of the invention. A first mixer 702A implements a BRSK narrow band system. The second mixer 704A then spreads the signal by mixing it with a fast burst symbol cycle signal from the burst symbol cycle generator 706A. A second mixer LO input is used to block signal during OFF periods of burst symbol cycles by timely applying a zero signal from the burst symbol cycle generator

706A. Mixers, which are three-port RF components utilized to modify a frequency of an input signal, are commercially available from many companies, such as HD Communications Corp., Ronkonkoma, New York. Voltage of amplifier 708A is switched 710A between burst symbol cycles to reduce the transmit power consumption, which is one way in which the methods of the invention can be used to allow low power consumption. Burst symbol cycle generation, such as by the burst symbol cycle generator 706A depicted in FIG. 7, can by implemented in several different ways.

FIGs. 8 and 9 are block diagrams depicted two techniques that can be utilized in generating bursts (of burst symbol cycles). FIG. 8 is a block diagram depicting a shift register based implementation of parallel loading for generating burst symbol cycles, which can be utilized in the transmitter depicted in FIG. 7, according to one embodiment of the invention. In the technique depicted in FIG. 8, burst symbol cycles are generated utilizing slow parallel loading 802AA, 802BA, 802CA, 802DA, 802EA and fast release. For example, assuming a ON period including five chips, each of the five chips can be loaded in parallel into the register, and a system clock is used to serially expel the chips.

FIG. 9 is a block diagram depicting a multiplexer based implementation of parallel loading for generating bursts, which can be utilized in the transmitter depicted in FIG. 7, according to one embodiment of the invention. The technique depicted in FIG. 9 utilizes slow parallel loading 902Aand multiplexing utilizing a fast multiplexer 904A For example, in a multiplexer based implementation, loading of five chips, for example, can be accomplished identically to that described in the embodiment depicted in FIG. 8. In the embodiments depicted in FIG. 9, however, a counter can cycle from one to five and control the multiplexer 904A and the multiplexer can expel the chips serially.

In addition to the methods described above for generating bursts, in some embodiments, ternary modulation can be used (see, for example, the carrierless

implementation described in Appendix C of previously incorporated by reference U.S. Provisional Patent Application No. 60/404,070).

FIG. 10 is a block diagram 1000Aof an implementation of a receiver that can receive burst symbol cycle transmissions, according to one embodiment of the invention. As depicted in FIG. 10, the receiver is implemented utilizing correlation of a received, or input, signal with an unmodulated version of the input burst symbol cycle. As depicted, correlation is implemented by multiplying the received signal with the unmodulated burst symbol cycle generated by a burst symbol cycle generator 1002A followed by matched filtering to the sequence length. For example, in some embodiments, a filtering and sampling technique can be used, in which, after multiplying a carrier and a short sequence, a low pass filter can be used based on the ON period where a signal is being sampled in a maximal energy state (See FIG. 11). Alternatively, an "integrated and dump," or I & D, technique can be used.

In any of the embodiments depicted in FIGs. 8-10, a switch can be used as an initial component to block out noise during OFF periods.

FIG. 11 is a timing diagram that depicts characteristics of a burst symbol cycle reception, according to one embodiment of the invention. Specifically, FIG. 11 depicts transmitted, or TX, signals and received, or RX, signals over time while a receiver according to one embodiment of the invention is synchronized with a transmitter burst symbol cycle generator. The allowed sampling time window 1102A begins at the start of an OFF period. It is to be noted that a single base band filter can be utilized to accommodate many different information transfer rates, or bit rates, because the filter is matched to sequence length rather than bit rate. Substantial flexibility is provided in terms of the accuracy of the filter bandwidth because integration in area with no signal or noise, i.e., the OFF period, does not change the output signal to noise ratio. In addition, using a burst symbol cycle allows for AC coupling in the base band with a single and higher cutoff frequency.

FIGs. 12-14 describe signal tracking and acquisition according to some embodiments of the invention. FIGs. 12-14 relate to a packet-based signaling implementation, in which a receiver must acquire and track a signal on a packet-by-packet basis. While FIGs. 12-14 relate to a packet-based signaling implementation, it is to be noted that other embodiments of the invention are contemplated which use non-packet-based signaling implementations.

FIG. 12 is a state diagram depicting states 1200A associated with signal acquisition and tracking by a receiver, according to one embodiment of the invention. State 1 1202A represents a receiver in an idle mode, which can be a power-saving low power mode, waiting for a signal. Upon identification of a signal, the receiver assumes state 2 1204A.

The State 2 1204A represents a receiver state in which automatic gain control (AGC) is activated during fast calibration of the received signal, or received signal chain. Upon stabilization of gain, an automatic gain control loop is switched to slow gain control for the remainder of the information packet, and the receiver assumes state 3 1206A.

The state 3 1206A represents sequence acquisition, in which the receiver attempts to synchronize on a transmitter sequence phase while searching to detect $I^2 + Q^2$ energy, perform $I^2 + Q^2$ correlation, using a clock swallow mechanism (a known technique used in DSSS systems for acquiring sequence phase in, for example, a DSSS system). While detecting energy, early-late dither (a known technique used, for example, in DSSS systems) is being performed to detect an exact phase in order to detect a burst symbol cycle center using fine step search, or early-late dither, in a burst symbol cycle generator of the receiver. In some embodiments, if acquisition at state 3 1206A is successful, state 4 1208A is assumed; if acquisition is unsuccessful, the state 1 1202A is assumed.

The state 4 1208A represents carrier acquisition, at which the receiver estimates the transmitter carrier phase using In phase and Quadrature (I and Q) signals (phase

detection). In some embodiments, if the detection is successful, the receiver assumes state 5 1210A; otherwise, the receiver 1200A assumes the state 1 1202A.

The state 5 1210A represents phase tracking, at which the receiver is in a tracking mode and utilizes a Costas loop for phase tracking. Costas loop tracking generally includes using two correlators with 90 degree separation between the locals (I and Q), multiplying I and Q, and, after using a loop filter to control the clock, tracking the carrier signal. Because the receiver utilizes a single clock, this tracking also maintains the sequence phase. When the information packet ends, the receiver assumes state 1 1202A. It is to be noted that a Costas loop tracking system can also be used in carrierless embodiments of the invention.

In some embodiments, there is no need for resynchronization between bits, i.e., no need for resynchronization between ON periods (after initial synchronization), and tracking is based on receiver VCXO stability. For example, in a reception situation involving 10MHz bits, a 10nsec ON period, and a 90nsec OFF period, the receiver VCXO is sufficiently stable to maintain its frequency and phase over burst symbol cycle durations.

FIG. 13 is conceptual diagram 1300A graphically depicting $I^2 + Q^2$ correlation as performed at state 3 1206A of FIG. 12, according to one embodiment of the invention. In-phase mixer output 1302A, quadrature mixer output 1304A, and $I^2 + Q^2$ output are depicted.

FIG. 14 is a timing diagram that depicts characteristics 1400A of packet transmission with non-burst symbol cycle, continuous preamble transmission, according to one embodiment of the invention. In the embodiment depicted in FIG. 14, for fast synchronization on a new packet of information, in the preamble portion 1402A of each packet, a continuous transmission is utilized. The payload portion 1404A, however, is transmitted (and received) as a burst symbol sequence. After the initial synchronization, the OFF periods between ON periods of the burst symbol sequence transmission are sufficiently

short that re-synchronization between ON periods is unnecessary, increasing system efficiency.

FIG. 15 is a flow diagram depicting a method 1500A of transmission, according to one embodiment of the invention. At step 1502A, signal scrambling is performed to create a "white" source without a DC component. In relatively low bit rate situations, to more sufficiently move the signal away from DC, additional multiplying utilizing a several MHz clock can be performed, such as, for example, Manchester coding (for example, using a "0" signal followed by a "1" signal to code for a positive bit, and a "1" signal followed by a "0" signal to code for a negative bit). At step 1504A, coding of the signal is performed, allowing improved interference resistance. At step 1506A, interleaving of the signal is performed, which combats burst error. At step 1508A, each bit or group of bits is mapped into a sequence of chips, based on the bit value and a burst symbol cycle generator. At step 1510A, filtering according to a required mask is performed and the signal is sent to an antenna of a transmitter performing the method 1500A. Finally, at step 1512A, the signal is transmitted in a burst symbol cycle manner, with ON period/OFF period durations varying with bit rate. For example, in some embodiments, in an instance of single bit mapping to sequence a given bit utilizing a 10 MHz bit rate and a 1 GHz chip rate, burst symbol cycles can be utilized with ON periods during which 20 chips are transmitted and an OFF period of four times that duration.

FIG. 16 is a flow diagram depicting a method 1600A of reception, according to one embodiment of the invention. At step 1602A, a received signal is switched in accordance with a burst symbol cycle, reducing noise and interference. At step 1604A, the signal is de-correlated using a sequence and mapping function corresponding to those utilized by the transmitter that transmitted to received signal. At step 1606A, the output signal is filtered using an AC coupled to a low pass filter (note that the presence of OFF periods

allows a less accurate filter to be used than would otherwise be required). At step 1608A, the output signal from step 1604A is sampled using an A/D. At step 1610A, samples are decoded in order to estimate a value for I, which is used in de-interleaving, de-scrambling, and de-coding to obtain information.

FIG. 17 is a flow diagram depicting a method 1700A of burst symbol cycle signal acquisition and tracking by a receiver, according to one embodiment of the invention. At step 1702A, acquisition is performed by searching a phase of a burst symbol cycle generator signal utilized by a transmitter that transmitted the received signal. At step 1704A, a known jitter function (sine function) is introduced into a system clock. At step 1706A, the receiver locks on to the jitter function. At step 1708A, the receiver uses the jitter function to estimate frequency and phase errors, thereby avoiding the need for early/late correlators.

FIG. 17A is a graph 1750A depicting a spectrum of a signal in which each burst is transmitted using a different frequency. In some embodiments of the invention, each burst is transmitted in a different frequency. Furthermore, in some embodiments, each burst is transmitted in more than one frequency. Additionally, in some embodiments, the frequency or frequencies can be selected according to information to be transmitted, a pseudo-random sequence, or both.

FIGs. 18-20 are block diagrams that provide examples of configurations and implementations of transceivers in accordance with some embodiments of the invention. FIG. 18A is a block diagram depicting an implementation 1800A of a transceiver, according to one embodiment of the invention. FIG. 19 is a schematic diagram depicting an implementation 1900A of a transceiver, according to one embodiment of the invention. In the implementation depicted in FIG. 19, the transceiver uses time division duplex technique, which can enable reuse of some elements of the transmitted signal (TX), or signal chain, and the received signal (RX), or signal chain. FIG. 20 is a schematic diagram depicting another

implementation 2000A of a transceiver, according to another embodiment of the invention. Specifically, FIG. 20 depicts a full QAM transceiver, including a transmitter 2004A portion and a receiver 2006A portion. The transmitter 2004A portion of the transceiver includes a QPSK mixer 2002A and two DACs 2008AA, 2008BA. For example, using 16QAM, one of 16 sequences can be transmitted during an ON period, using 4 different amplitude levels on the I and Q. Using this technique, 4 bits can be mapped into one symbol, in accordance with the equation:

$$S=(A+2B)Sin+(C+2d)Cos$$

where S is the symbol, and A, B, C, and D are each bits having a value of +1 or −1.

In some embodiments of the invention, I and Q carriers can be replaced by a wide band signal and a delayed version of the wide band signal in a transmitter and in a receiver. Additionally, in some embodiments, I and Q carriers can be replaced with a wide band signal and a 90 degree phase shift of the wide band signal (Hilbert transform) in a transmitter and in a receiver.

In some embodiments, the duration of each ON period and OFF period is adaptively changed in order to accommodate variable parameters, such as maximum power usage rate requirements, minimum data transfer rate requirements, range dictated requirements, or other parameters. For example, in some embodiments, the methods and systems of the invention can operate in different bit rate modes by varying ON and OFF period lengths or other parameters. For instance, In one embodiment, a low bit rate mode, middle rate mode and high bit rate mode are available. The low bit rate mode utilizes the following transmission parameters: a bit rate of 1 MHz, an ON period length of 10 nsec during which 10 chips are transmitted, an OFF period length of 990 nsec, a BPSK symbol modulation time of 1000nsec, a chip rate of 1 GHz (chip time of 1nsec), a carrier signal frequency of 4GHz, and a signal spectrum of between 3 GHz and 5 GHz. The middle bit rate

mode utilizes the following transmission parameters: a bit rate of 10 MHz, an ON period length of 10 nsec during which 10 chips are transmitted, an OFF period length of 90 nsec, a BPSK symbol modulation time of 100nsec, a chip rate of 1 GHz (chip time of 1nsec), a carrier signal frequency of 4GHz, and a signal spectrum of between 3 GHz and 5 GHz. The high bit rate mode utilizes the following transmission parameters: a bit rate of 200 MHz, an ON period length of 5 nsec during which 5 chips are transmitted, an OFF period length of 15 nsec, a 16QAM symbol modulation time of 20nsec, a chip rate of 1 GHz (chip time of 1nsec), a carrier signal frequency of 4GHz, and a signal spectrum of between 3 GHz and 5 GHz.

In some embodiments, techniques other than 16QAM symbol modulation are utilized to provide high bit rate transmission. For example, in some embodiments, ON periods are utilized in which multiple bits are transmitted. In some embodiments, multiple bits are converted to a symbol, and a symbol is transmitted during an ON period, so that multiple bits are transmitted per ON period. For example, utilizing this technique, 200 MBPS rates are achievable, with 50 M sequences transmitted per second. In other embodiments, bits of information themselves can be transmitted in an ON period, instead of chips. For example, utilizing this technique, 100MBPS rates are achievable by utilizing 10 nsec ON periods during which 10 bits are transmitted, 90 nsec OFF periods.

The methods and systems of various embodiments of the invention can provide numerous advantages over known wireless transmission systems. In some embodiments, transmitters and receivers, as described herein, use much less power than typical known systems utilizing DSSS. In some embodiments, transmitters and receivers and described herein operate utilize low power during ON periods and can utilize even less power during OFF periods by assuming very low power modes. In some embodiments, the methods and systems described herein provide better multipath fading resistance. In some embodiments, transmitters as described herein provide the advantage of much lower peak

power usage, and more desirable peak to average ratios, as compared with typical known pulse transmitters. In some embodiments, as described above, the burst symbol cycle transmissions allow the use of a simplified and less accurate filter for ISI limitation as compared with non-burst symbol cycle systems, and also allow less accurate switch timing for a given specific performance. Additionally, the burst symbol cycle transmission techniques described herein provide advantages in a multiple access non-synchronization situations, including interference between signals intended for different users. It is to be noted that some embodiments of the invention are applicable to different multiple user applications or contexts, as described above.

FIGs. 21-26 are block diagrams that pictorially represent various configurations of digital devices and gateway servers, in which various embodiments of the invention can be utilized to provide multiple, simultaneous, high-speed data communications, utilizing burst symbol cycle UWB communications. As depicted, each server and digital device includes a transceiver to enable communication in accordance with the invention. In other embodiments however, where only one-way communication is required from, for example, a gateway server to a digital device, the gateway server can include a transmitter (and not a receiver) and the digital device can include a receiver (and not a transmitter).

Specifically, FIG. 21 depicts a home gateway server 2102A, which can, in some embodiments, be implemented as in a set top box configuration, connected to multiple digital devices 2104A, according to one embodiment of the invention. FIG. 22 depicts gateway server which is an audio/video server 2202A, connected to multiple audio/video digital devices in several different rooms 2204A of a house, according to one embodiment of the invention. FIG. 23 depicts multiple digital devices 2302A, each connected to a projector 2304A, according to one embodiment of the invention. The projector can, for instance, be utilized to provide large screen entertainment based on audio and visual data communication

from the digital devices. FIG. 24 depicts a DVD player 2402A connected to multiple television sets 2404A, according to one embodiment of the invention. FIG. 25 depicts a diagram of an in-building wireless network 2500A topology, according to one embodiment of the invention, spread between three rooms A-C 2502A of a building. FIG. 26 depicts a network 2600A including a home gateway server 2602A and numerous digital devices 2604A within a house 2606A, according to one embodiment of the invention. As depicted in FIG. 26, some of the digital devices 2604A communicate with the home gateway server 2602A, some with other of the digital devices 2604A, and some with both.

In some embodiments, in a system using UWB communication, signals may be transmitted using multiple bands. The following is a description of multi-band UWB communication systems and methods.

FIG. 27 depicts a frequency vs. power spectrum magnitude chart 700B of a multi-band UWB implementation, according to one embodiment of the invention. FIG. 27 illustrates an embodiment in which the spectrum is divided into a specific number of sub-bands with partial overlap. This divided spectrum has a bandwidth above 500MHz in order to meet the FCC requirement for UWB. In some embodiments all the bands are used, while in other embodiments the bands are divided into groups. An example depicting two overlapping groups of 15 sub-bands is depicted in FIG. 27.

Various transmission schemes and methods, or combinations thereof, are used in various embodiments of the invention, and are discussed briefly as follows. A band in use can be changed every one or more symbols. Each burst can be transmitted in a different frequency. Each burst can be transmitted in more than one frequency. Additionally, in some embodiments, the frequency or frequencies can be selected according to information to be transmitted, a pseudo-random sequence, or both. The transmission can be continuous, for example, when using the maximal pulse rate, or discontinuous, for example, when using

lower rates. Several bands can be used in parallel. The information can be coded on the different bands using any modulation technique including Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM), Ternary signals, Orthogonal Frequency Division Multiplexing (OFDM), Pulsed OFDM, multi code (for example, combining of Hadamard sequences), Pulse Position Modulation (PPM) or by selecting the band according to the information. Coding can be added to improve the performance. A difference between different sub-bands can be averaged using channel state information in a transmitter, a receiver, or both.

In embodiments using pulse systems, the pulse repetition interval can be reduced to allow for reduced sampling rates, reduced power consumption, improved inter-symbol interference (ISI) mitigation, improved energy collection and improved multiple-access.

In some embodiments, where the frequency range is divided into sub-bands, two overlapping groups of 15 sub-bands are divided, although use of less than 15 sub-bands in any specific link is possible. As FIG. 27 illustrates, Group A includes 15 Sub-bands with spacing of 470 MHz. Group B also includes 15 Sub-bands, which overlap the first group but are shifted 235 MHz aside. This method enhances system flexibility with respect to co-existence, interference mitigation and multiple-access. Each sub-band is generated by a pulse with 10 dB bandwidth of ~520 MHz.

Some embodiments provide advantages in interference and co-existing. In some embodiments, one or several bands are eliminated while detecting an in-band interferer like 802.11A. This achieves a better selectivity for out of band interference based on the fact that the bands are narrow relative to a single band system.

In some embodiments, by transmitting each symbol in a different band according to a known sequence, a better resistance to ISI is achieved. This is based on the low pulse repetition interval per sub-band.

In some embodiments, each piconet uses a different time frequency interleaving sequence. The sequence is based on a pseudo-random sequence or a pre-determined sequence. Different phases of the same sequence can also be used in synchronized or semi synchronized cases. In some embodiments, a color code can be added above the sequence to increase the number of possible sequences and piconets. FIG. 28 depicts a table 800B of time-frequency interleaving sequences, and provides an example of the use of 7 bands according to the sequence. The seed sequences of time frequency interleaving are defined in a way that when using two unsynchronized sequences in two piconets only a single collision is expected at all phases.

In some embodiments, the same seed sequence is used for lower pulse repetition intervals, reduced number of sub-bands, or transmission of sub-bands in parallel.

In some embodiments, there is an option to stay in the same frequency for more than one symbol. This improves performance and improves multiple access, allows energy collection, and simplifies the wave generator, for example, by allowing slower frequency switching.

In some embodiments, the bands can be used in a burst mode. Either a burst in a given frequency followed by an off period, or a burst of frequencies followed by an off period.

Some embodiments implement single, double or parallel chains. In many instances, a one receiver option can be the simplest solution and have the best current efficiency. Using parallel receivers with each receiver dedicated for each band enables energy collection for each band. Generally, this option requires a bigger die size and more

power. Some embodiments may use two or more chains, which in some circumstances can help mitigate undesirable properties that may be present.

In some embodiments, in order to generate a rake receiver, either parallel receivers are used (e.g. work in parallel on all bands or divide the bands between them), or in the case of lower pulse repetition intervals, the same receiver is used.

FIG. 29 is a block diagram 900B providing an illustration of a multi-band signal generator according to one embodiment of the invention. At block 901B, scrambling is performed (to prevent a sequence of zeros or ones), coding is performed (to correct errors), and interleaving is performed (to eliminate burst of errors). Block 902B contains a stream demultiplexer (for example, a serial to parallel demultiplexer, where each output goes to separate sub-band), and inner coding (where there is a different code or different code rate for each band, and where some sub-bands have a different link budget according to either the frequency attenuation slope in the air or according to interference). Block 903B includes a multiplexer (for example, a parallel to serial multiplexer, with a serial output). Blocks 904B and 905B are IQ modulators where each symbol is modulated on another sub-band. The upper-bands modulator 905B is optional and may be used to transmit two symbols thereby supporting a higher bit rate.

In some embodiments of the invention, an Ultra Wide Band (UWB) system may be used to transmit high bit rate information. In some embodiments, transmitting using UWB, the data stream can or must be transformed. The following discussion provides examples of techniques for transforming data sequences to be transmitted using UWB transmission. According to various embodiments of the invention, transmission schemes can include transmitting on an entire UWB spectrum, or on sub-bands of the UWB spectrum using multi-band UWB.

A transformation can be performed on a data sequence, for example, to decrease the transmission time of the original data signal to be sent. In some embodiments, the data signal is collected and sent as burst. FIG. 30 is a timing diagram 1000B showing one embodiment of such a burst scheme. In some embodiments of the invention, a few or multiple bits are collected by the transmitter and are subsequently transmitted in a burst as a fast sequence, one example of which is illustrated in FIG. 30. The data signal 1002B represents a sequence of zeroes and ones, to be transmitted over 1 microsecond. The sequence is condensed to a 10 nanosecond burst of data and a 90 nanosecond silent period. Signal 1004B represents the condensed burst transmitted signal. FIG. 30 illustrates which data bits are translated into which burst signal. In various embodiments, the transformed signal 1004B may be transmitted using one of the schemes from FIG. 30, discussed subsequently herein.

In some embodiments utilizing the aforementioned burst transmission scheme in FIG. 30, random positioning can or must be used for each transmitted sequence. Coding may not be able to adequately distinguish between users in a multiple access system because each user may use all sequences. Therefore, in some embodiments, the burst sequence is transmitted in a random position in the symbol cycle.

FIG. 31 is a timing diagram 1100B that depicts a symbol mapped transmission, according to one embodiment of the invention. As depicted in FIG. 31, the data sequence 1102B mapped to a symbol. A few or multiple bits are collected and converted to a symbol, each symbol to be transmitted as a different sequence. In some embodiments, the data bits are converted into a longer sequence of bits that will be transmitted in a shorter period of time. One example, as depicted in FIG. 31, is to convert every 4 data bits into one of 16 different sequences. This transformation is performed by mapper 1104. For each combination of 4 data bits 1102B, one symbol 1106B will be transmitted. The symbol

sequence contains more bits but is transmitted in a shorter period of time. In this way, 40MBPS with 10M Sequences Per Second can be transmitted, when the symbol is 4 bits. The sequence duty cycle can be 10nsec on, to transmit the symbol, and 90nsec off. In some embodiments, the transmission schemes depicted in FIG. 30, described subsequently herein, may be used.

In some embodiments, the above scheme may be used for a medium data rate transmission like 40MBPS. With a higher bit rate like 200MBPS, it may be necessary to map every 16 bits of the data signal to each symbol. In that case a mapping from 216 to 216 sequences will be a mapping of bits themselves, as in the scheme illustrated in FIG. 30. Since, referring to FIG. 31 and assuming transmission of one 10 ns burst for every 100 ns, with a bit rate of 40Mbps 4 bits are mapped to a symbol. Similarly, with a rate of 200 Mbps, 20 bits are mapped to a symbol. There is therefore, in that case, a need for a minimum of 20 chips per symbol. The mechanism depicted in FIG. 30 does not need the mapping coding gain, which is needed in the slower bit rates.

In some embodiments, the encoded sequences should generally be selected with a maximal distance between the different codes. For example, Walsh-Hadamard orthogonal sequences can be used. Alternatively, other sequences like PN sequences, Barker sequences, Gold sequences or Kasami sequences may be used.

Multi-band transmission schemes can include pulsed or burst OFDM transmission. FIG. 32 is a timing diagram 1200B that depicts a pulsed OFDM transmission, and FIG. 33 is a timing diagram 1300B that depicts a burst OFDM transmission. In some embodiments, such as illustrated in FIGs. 32 and 33, the transformation of the data sequence is based on the Inverse Fast Fourier Transform (IFFT) in the transmitter and the Fast Fourier Transform FFT in the receiver, similar to orthogonal frequency division multiplexing (OFDM) transmission. This technique can be essentially a digital version of OFDM using

orthogonal sequences, in which case a multi-level signal can be transmitted by bursting or pulsing a narrow band digital signal.

Using the multi-band UWB scheme such as described above, a pulsed or a burst OFDM signal can be transmitted over the UWB range. In some embodiments, the band in use can be changed after one pulsed OFDM symbol has been transmitted. Alternatively, the band in use can be changed after several OFDM symbols have been transmitted.

In some embodiments, discontinuous, or burst symbol cycle, transmitting is used. One advantage of using burst symbol cycle transmission is that the Fast Fourier Transform (FFT) rate using burst symbol cycle transmission is lower than the FFT rate in a continuous OFDM system.

In one embodiment of the invention, a train of OFDM pulses is transmitted, as depicted in FIG. 32. In the depicted scheme, a pulse-train is transmitted on one sub-band before switching to the next sub-band according to the time frequency sequence. This technique uses a narrow band OFDM signal generator. The original data sequence 1202B is transformed into a sequence of pulses 1206B using the IFFT 1204B. In the pulsed scheme, the transmission of the pulses takes the length of the symbol time 1208B. The relatively narrow OFDM signal is widened by pulsing the signal.

In FIG. 33, an embodiment utilizing a burst OFDM scheme is shown. In some embodiments, at each sub-band a burst of OFDM pulses is transmitted, as depicted in FIG. 33. In the depicted scheme a burst is transmitted on one sub-band before switching to the next sub-band according to the time frequency sequence. This technique can use a narrow band OFDM signal generator. The narrow OFDM signal is widened by bursting. The original data bits 1302 are transformed using the IFFT 1304B and transmitted as a burst 1306B. The transmission as depicted in FIG. 33 generally is faster than that depicted FIG. 32

and takes a fraction of the symbol time. In some embodiments, the transmission schemes of FIG. 40 may be used.

FIG. 34 is a block diagram depicting an implementation of multi-band pulsed OFDM. Transmitting pulsed OFDM in each sub-band of a UWB system, as depicted, can allow the system to stay in the same frequency for longer periods of time while being able to cope with ISI problems. Coding is performed by 1401B. After the interleaving 1402B, there is a serial to parallel converter 1403B, which generates a parallel word for the pulse OFDM generator 1404B. The serial to parallel converter 1403B generates the symbols used in Fig. 32 (each symbol is going to be transmitted on a different band). The channel multiplexer 1405B takes the symbols and converts it back to a serial stream and passes it to the QPSK modulator 1406B.

Schemes such as that depicted in FIG. 34 generally can provide certain benefits, such as the following: slower band change rate, or simpler wave generation; improved channelization under interference associated with multi-path characteristics; improved energy collection; and better resistance to ISI based on the OFDM. Generally, some of the tradeoffs of schemes such as depicted in FIG. 34 can include the fact that implementation is generally more complex, and peak-to-average increased, relative to other multi-band systems.

FIG. 35 is a block diagram 1500B depicting one implementation of a burst OFDM transmitter and receiver mechanism. A few bits are collected. Each bit can be +1 or –1. The bits are converted as if they were a frequency spectrum into digital values using IFFT 1502B. The signal is converted using a parallel to serial (P/S) converter 1504B and a digital to analog (D/A) converter 1506B. The bursts are transmitted using analog values, instead of digital as in some previously discussed embodiments. The transmitter can use binary phase key shifting (BPSK) or quaternary phase key shifting (QPSK) modulation. On

the receiving side, the signal is converted using an analog to digital converter (A/D) 1508B then by a serial to parallel (S/P) converter 1510B and by a FFT 1512B.

FIG. 36 is a block diagram 1600B depicting an OFDM transmitter and receiver mechanism, according to one embodiment of the invention. Some embodiments, as shown in FIG. 36, use what can be a simpler implementation of an OFDM transmitter. A portion of the frequencies is used with a minimal distance between them. A sequence of filters is used in the transmitter and receiver instead of IFFT and FFT. A non-coherent receiver is implemented using energy detectors. The wide band signal generator on the transmitter 1610BB side includes a source 1611B, which generates a signal over the entire UWB spectrum. Each filter 1602B through 1605B is filtering a specific band. Therefore, whenever the wide band signal exists at the filter input, that specific band exists on the combiner 1614B input. The logic controls a sequence of switches in a manner such that every combination of the bands can be in the air at every moment. The receiver 1613B includes filters 1606B through 1609B and detectors, which can detect, in a non-coherent way, the existence of each band at every moment. This is an implementation of an OFDM transmitter, where parts of the frequencies are used with minimal distance between them (these are the sub-bands).

FIG. 37 is a chart 1700B depicting a frequency selection option implementation according to one embodiment of the invention. In some embodiments, as FIG. 37 illustrates, the implementation has a frequency selection option in addition to different burst positions. Using two planes as depicted in FIG. 37, either part of the information in plane A and part in plane B is transmitted, or the same information in both planes is transmitted. By doing so, the system generally can achieve a gain in diversity, i.e., resistance for both constant frequency interference and periodic time interference.

For example, in an embodiment using burst OFDM, the signal may be transmitted in multiple ways. The transmission mechanisms include transmitting every burst signal on a different band, transmitting several bursts on the same band, or sending all bursts on the same band. Similarly, in an embodiment utilizing pulsed OFDM, the signal may be transmitted in multiple ways. The transmission mechanisms include transmitting every symbol or train of pulses on a different band, transmitting multiple symbols or trains of pulses on the same band, or transmitting all symbols or trains of pulses on the same band.

Variations on transmission techniques are possible in various embodiments of the invention. For example, the jumping sequence may be short while in other embodiments it may be long. Also, the length of the jumping sequence may depend on, or may not depend on, the information. Additionally, the bands can be separate, can overlap, or can partially overlap. Furthermore the wave generator can be analog with a few carriers, or can include one carrier with frequency dividers. Alternatively, the wave generator may be digital with, for example, a two or three level digital signal. Furthermore, the frequencies may have a constant phase relation whereby they lock on the same reference, or the frequencies may not have a constant phase relation. Additionally, in some embodiments a few bands can be used in parallel, where each band contains different information. In other embodiments, the same information may be transmitted on multiple bands.

Various embodiments of the invention as described herein can provide many advantages compared to known alternatives. These advantages can include one or more of the following, among others: the ability to better deal with interference, less inter-symbol interference (ISI), better channel energy collection, better spectral shaping, and fast synchronization. In addition, some embodiments of the invention provide a solution for multiple access. In some embodiments, provides a tradeoff capability between better peak to average ratio (P/A) and higher bit-rate.

FIGs. 39 and 40 provide illustrations of three ways in which information can be transmitted. These transmission mechanisms can be used in embodiments of the multi-band UWB transmission schemes described above.

FIG. 39 is a block diagram 1900B depicting an implementation of multiple transmission schemes, which can be used exclusively or in some combination. As shown in FIG. 39, according to some embodiments of the invention, transmission can be accomplished in one of three ways. A narrow signal with a fast clock 1902B can be transmitted using one of the three mechanisms illustrated in the FIG. 39. In some embodiments, regular burst transmission 1904B is used. In other embodiments, the repeated burst transmissions 1906B within the symbol time are used to transmit information, which can provide an improved to the P/A ratio. In other embodiments, transmissions may be performed by repetitions, with codes in each repetition, or repetition with code 1908B, which can improve the spectral shaping of the signal and provide additional separation for multiple access.

FIG. 40 shows a timing diagram 2000B of the three possible transmission mechanisms In some embodiments, the signal may be sent as a burst 2002B, where the information 2014B is sent in beginning of the symbol time 2004B. The burst transmission takes one burst period, or burst time 2006B, to transmit, and the remainder of the symbol time 2004B is silent. In other embodiments, the signal 2016B is transmitted with repetitions 2010B. During one symbol time 2004B, the information 2016B is repeatedly sent. In other embodiments, the information 2018B is burst repeatedly 2012B with a code 2020B following each transmission.

Costas loop tracking can be used for phase tracking. A Costas loop generally includes using two correlators with 90 degree separation between the locals (I and Q), multiplying I and Q, and, after using a loop filter to control the clock, tracking the carrier signal. Because the receiver utilizes a single clock, this tracking also maintains the sequence

phase. When the information packet ends, the receiver assumes state 1 1202B. It is to be noted that a Costas loop tracking system can also be used in carrierless embodiments of the invention.

As described in more detail in previously incorporated by reference U.S. Application No. 10/389,789, the methods and systems according to various embodiments of the invention can provide numerous advantages over known wireless transmission systems, including, among others, reduced power usage, reduced interference, better multipath fading resistance, lower peak power usage, and more desirable peak to average ratios, the use of a simplified and less accurate filter for ISI limitation and the use of a less accurate switch timing for a given specific performance.

What follows is a discussion of multi-band UWB signal generators. A multi-band ultra-band transmission scheme is an extension of single band ultra-wide band (UWB) system. In a multi-band ultra-wide band system each band is itself a UWB signal. Each of the sub-bands may be a single band signal. The multiple signals can be transmitted together in serial or they can be transmitted in parallel on different frequency bands. Each sub-band, viewed independently, may utilize a discontinuous transmission scheme. Each of the sub-bands may, for example, use pulse and quiet time transmission or may be transmitted using an OFDM symbol and quiet time.

In some embodiments, signals may be transmitted on multiple bands using a burst symbol cycle, or discontinuous, transmission scheme. A burst symbol cycle transmission includes an ON period during which one or more symbols are transmitted, and an off period during which no signal is transmitted. Further details regarding burst symbol cycles and burst symbol cycle transmission can be found in previously incorporated by reference U.S. Application No. 10/603,372, filed on June 25, 2003

In some embodiments of multi-band ultra-wide band transmission or reception according to the invention, the same signal frequency and phase are maintained from the end of an ON period to the beginning of the following ON period. In some embodiments, the same signal frequency is maintained from the end of an ON period to the beginning of the following ON period.

Multiple bands may be generated in a number of ways. After the signals are generated various transmission schemes exist. In one embodiment, several sub-bands are transmitted in parallel, each independently utilizing on the discontinuous transmission scheme. In another embodiment, the various sub-band signals are transmitted staggered in time. In this last-mentioned embodiment the on period of the various signals may occupy a different period in time. While the overall time domain may or may not exhibit discontinuous behavior, each band viewed independently may still be discontinuous.

Each sub-band in a multi-band UWB may carry multiple data signals. Several pulse shapes may be combined to form a single UWB transmission, either as a single band transmission or as a single band of a multi-band transmission. In one embodiment, for example, both the I portion and the Q portion of a single frequency QPSK signal may carry separate data and may be transmitted on a single band.

FIG. 41 presents one embodiment of how multiple signal generators may be combined to generate one or more of the sub-bands in a multi-band UWB system. Each block 101AC through 101NC represents a different wave form that may comprise a single sub-band. In some embodiments, to generate multiple bands of a multi-band signal that will be transmitted in parallel, separate groups of wave generators 101C will be needed for each sub-band. If, in another embodiment, the signals are transmitted in serial, then the individual generators 101C may be re-used for different sub-bands.

In one embodiment, there are 14 possible pulse shapes. The 14 possible pulse shapes represent the sine and cosine of seven different sub-bands. Of those 14 pulse shapes, 4 may be transmitted together. That is, groups of two sub-bands are transmitted in parallel; the groups are transmitted in serial. Each of the four simultaneously transmitted shapes may carry different data. The four simultaneously transmitted pulse shapes represent the I and Q or sine and cosine of two different frequencies or sub-bands. On each pulse four bits of data may be transmitted. After transmitting a given set of pulses based on one set of frequencies, the next set of pulses may be selected from another two of the seven sub-bands. Multiple sub-bands can be sent in parallel and then later in serial.

In other embodiments, the number of possible sub-bands may be greater or less than seven. Furthermore, the number of bands transmitted simultaneously may vary. In addition, in other embodiments, the number of wave forms sent on a particular frequency can be greater or less than two. The order of the frequencies depends on the system and may vary across different systems.

Transmitting the different sub-bands in multiple orders allows multiple pico-nets to operate simultaneously. Multiple pico-nets could, in some embodiments, transmit using the same set of sub-bands while avoiding interference by cycling through the sub-bands where each pico-net uses a different order. Frequency order selection could, in some embodiments, be similar to FDMA, where sequences are checked to see which are in use and an empty one is selected.

In implementing a multi-band UWB signal generator it is desirable to implement a transmitter that can rapidly switch between frequencies. Having such a transmitter is more efficient from an implementation standpoint as it avoids a complex parallel transmitter or receiver.

In some embodiments, the transmitter may transmit (and the receiver receive) some subset of the possible sub-bands. To rapidly switch sub-bands and to allow for a continuous transmission of multiple sub-bands in serial, it is necessary to have a fast switching transmitter and receiver. What follows is a description of various ways to achieve fast frequency switching.

With reference to FIG. 42, a circuit diagram of one embodiment of a fast switching frequency generator is shown. The circuit comprises voltage-controlled oscillators (VCO) 201C and 202C, dividers 203C through 209C, a mux 212C and a mixer 213C. The dividers, normally used in a phase locked loop to generate a single frequency, are here used to generate multiple frequencies from a single center frequency.

In some embodiments, one or more analog wave generators are used. In some embodiments, one or more digital wave generators are used. Furthermore, in some embodiments, one or more wave generators are used that are combination digital and analog.

In the embodiment depicted in FIG. 42, two center frequencies are generated by VCOs 201C and 202C. The center frequencies are multiplied by integer multiples of a step frequency to generate multiple bands. Specifically, the step frequency is 440 MHz. The first VCO 201C generates a center frequency of 5280 MHz, which is itself a multiple of the step frequency. The center frequency is connected to a group of dividers 203C-209C, which output the various multiples of the step frequency. These step multiples are the input to the mux 212C, which outputs to the multiplier 213C. Various multiples of the step frequency can be selected by the selection of different inputs to the mux 212C. The multiplier 213C takes as its second input the center frequency and outputs the selected step multiple multiplied by the center frequency. In some embodiments in which QPSK modulation is used, an input signal is multiplied with a data signal prior to generating signals of different

frequency multiples of a step frequency, which can allow the use of a narrowband mixer, whereas, to modulate a multi-band signal, a wideband QPSK mixer can be required.

In order to switch frequencies, the input to the mux 212C is switched, which changes the multiple by which the center frequency is being multiplied. In this embodiment, all the frequencies are available at all times so that switching can be accomplished rapidly without waiting for components to stabilize. In addition, only one VCO is necessary.

In certain embodiments, the addition of a second VCO 202C allows frequencies to be generated where the center is not a strict integer multiple of the step frequency. In this embodiment the second VCO 202C produces a center frequency of 5060 MHz, which is 11.5 times the step frequency.

The table 214C shows the various channels or sub-bands generated from the two center frequencies, Group A and Group B. Having two center frequencies helps to avoid interference across multiple bands. That is, if interference is detected in two adjacent bands, thereby rendering them useless, another center frequency can be selected, thereby moving the interference to a single band for greater bandwidth utilization.

In other embodiments, other center frequencies and step frequencies may be used. In addition, in other embodiments, switching components off when not needed may improve (decrease) current consumption. For example, in some embodiments, during OFF periods of transmissions or receptions, power is switched or cycled off with respect to a transmitter, a receiver, or one or more components or circuits thereof.

Digital Signals, for example, those generated by the circuit in FIG. 42, have harmonics. In addition to the desired output signal, there is an unwanted output of a signal on undesired frequencies due to the harmonics.

In one embodiment, the harmonics may be removed using filters. One negative aspect of using filters is that they occupy a large space in a circuit. In addition, they are analog and hard to calibrate and manufacture.

With reference to FIG. 43, a way of digitally removing harmonics is presented. Clock signal 301C represents a signal with undesired harmonics. In this embodiment all the even harmonics are absent from the signal because of the 50 percent duty cycle of the clock. The third harmonic is removed by delaying the clock cycle by T/6, as shown by reference number 302C. When the delayed clock 302C is subtracted from the clock 301C a ternary signal 303C results. The new signal 303C has the same frequency as the original clock 301C but the third harmonic is absent.

In one embodiment, the clock can be the step frequency of 440 MHz used in FIG. 42. Since the clock operates at a 50% duty cycle, the even harmonics are not present. The third harmonic lies in a band where interference should be limited, and therefore the harmonic should be removed. The next harmonic, the 5th, lies outside the range of concern.

In some embodiments, the processing may be accomplished without the use of digital to analog converters. Almost all the processing is done digitally without the need for analog components. The subtractor may be analog.

The subtraction, in some embodiments, may be accomplished by connecting the two streams to the differential inputs of a mixer. In such an embodiment a switch mixer may then be used, rather than a linear mixer. This mechanism may be used generally to generate a three level or ternary signal from two binary signals.

In another embodiment, the fifth harmonic can be removed by subtracting two ternary signals. By using a delay smaller than T/6, for example T/10, the fifth harmonic can be removed. To remove both the third and the fifth harmonics together the method would need to be performed twice. A signal delayed T/6 is subtracted from the original clock

signal. The result of first subtraction is delayed by T/10 and subtracted from the result of the first subtraction. The resulting signal has both the third and the fifth harmonics removed.

In one embodiment, this result is implemented using binary signals. The first set operates as in FIG. 43, this first result being a signal with no third harmonic. A second signal is generated by subtracting a clock delayed by an additional T/10 from the original clock frequency. This second result is the first result delayed by T/10 or a delayed version of the original clock without the third harmonic. The difference of the second result and the first result is the original clock without the third and fifth harmonics.

In other embodiments, different phases of the frequency can be generated. This can be done using only digital elements with no need for an additional mixer to modulate the data onto the carrier. Different delays of the original clock can produce different phases of the output signal. In addition, hopping can be done in zero time allowing for back to back pulses. One embodiment uses different phases of the dividers in the circuit to achieve this.

In rapidly switching between frequencies for sub-bands, it is important that transmissions on any given frequency remain consistently in phase. One way of achieving phase consistency is shown in table 400C of FIG. 44. In the table the actual transmitted signal is designated "Multi Carrier". The Multi Carrier is an aggregate signal comprising segments from three sub-bands designated carriers A, B, and C. The Multi Carrier will transmit on each frequency in a round robin fashion starting with carrier A then rapidly switching to carrier B, then rapidly switching to carrier C and then back to carrier A.

When returning to a specific carrier, resuming the sequence from the last transmitted point will result in shifting the phase of the carrier signal in the transmitted signal. Rather, the transmitted signal should continue from the point where the carrier signal would have been, had it been transmitted continuously.

For example, in the embodiment illustrated in FIG. 44, each carrier signal is divided into 4 equal length segments. Each segment represents a carrier wave without data. Each segment may contain numerous binary or ternary bits. The Multi Carrier transmits the first segment, shown as "1A" from carrier A. When rapidly switching to carrier B, the multi-carrier signal will begin with segment 2B of carrier B. That is, it will operate as if segment 1B of carrier B had been transmitted. In such an embodiment, the multi-carrier needs 12 segments to transmit all segments of all carriers. This scheme ensures phase consistency among and between carrier signals.

The scheme depicted in FIG. 44 is well suited for a completely digital transmission mechanism. In contrast to the generator in Fig 42, where each frequency is being continuously generated and switched to when needed, and therefore there is no danger of the signals becoming out of phase, a fully digital scheme only produces a carrier wave when needed. It is therefore important to ensure that the phase will be coherent. For example, the signal 303C in FIG. 43 may be described by a sequence of 1's, 0's and –1's. The signal may be described in a higher resolution than the actual frequency, i.e. the zero in the signal could be represented by "0000". The signal would be divided into 4 equal length segments as depicted in FIG. 44. In that embodiment, two other carriers would be encoded similarly. Each carrier could be stored as a template in RAM and the signal generator that produces the Multi Carrier would transmit the stored sequences in the order described in table 400C.

With respect to FIG. 45, a system for generating various sub-band carrier waves using digital to analog converters (D/A) and shift registers, is presented.

For each of N transmitted sub-band carrier waves there is a D/A, 501AC-501NC. Each D/A is programmed to output a portion of the analog carrier wave based on a given input. Each D/A may have a different set of analog quantization levels. For example,

in one embodiment the D/As are 32 bits, each input bit will produce 1/32 of the output carrier wave. By cycling through the inputs the entire analog carrier wave can be produced.

A shift register 502C is used to cycle through the possible inputs, in order. In the embodiment being discussed a 32 bit shift register is used. Input to the shift register is a one followed by only zeros, which produces an output of 1. As the bits are shifted the one is shifted and subsequently produced at each of the outputs consecutively. When the one reaches the end of the register it is cycled back as the input and the process repeats.

Each output is attached to the inputs of the D/As so that a one on the first output of the register produces the first portion of the analog carrier wave.

Referring back to FIG. 44, the desired sequence for overall output is to switch between various pieces of each carrier wave. In one embodiment, if each carrier wave is represented by 32 bits and divided into 4 sequences, each sequence would be 8 bits. That is, bits 0 through 7 would produce the first sequence, and so on. To switch between outputs of the D/As 501AC-501NC an element is used to select the frequency after the output port 503C. That is, all carrier waves are generated simultaneously and selected outputs are transmitted based on a given sequence. In other embodiments, the output of the shift register may be redirected to different D/As when output of that carrier wave is needed.

In other embodiments, the carrier waves may be represented by any number of bits. The D/A and shift registers may then be of any bit size.

The pulses generated by the previous embodiments are given an envelope to control the shape of the frequency. Multiplying the signal in the time domain by a sine wave changes the shape of the frequency spectrum by reducing the side lobes and widening the bandwidth. In one embodiment, the side lobes are reduced from approximately 13 dB below the center to approximately 23 dB below the center. The envelope sine wave has a frequency

lower than the carrier frequency. In one embodiment it is a 4 ns wave compared to the 250 ps carrier frequency.

With reference to FIGs. 47A and 47B, a graph of the time domain and frequency domain of a signal with an envelope is shown. FIG. 47A shows the carrier signal -- the signal with the high frequency, shaped by half a sine wave. The frequency spectrum of that signal is shown in FIG. 47B. The side lobes are about 23 dB below the center frequency. This presents an improvement over the carrier frequency with a square shape, one with no envelope, which would have side lobes that are only about 13 dB lower than the center.

FIG. 46 presents one embodiment of a circuit that can be used to multiply the carrier signal by an envelope. The input sine wave 601C is sent through a half-wave rectifier 602C that will result in just the positive half of the sine wave. Usage of the rectifier, through adjustment of the threshold, allows for control of the spectral behavior of the resultant half sine wave. For example, increasing the threshold reduces the size of the remaining wave, thereby decreasing the length of the pulse of the envelope. The envelope would remain constant for all different sub-bands. Differences in the sub-band frequencies would be seen, for example in FIG. 47A, as differences of the frequencies within the envelope. The carrier wave would be input in the input 603C. The rapidly switched frequencies would all input to the circuit at 603C and would be multiplied by the envelope sine wave from the rectifier 602C. In some embodiments, pulse bandwidth is changed while pulse repetition frequency remains constant, to facilitate control of signal spectrum characteristics and receiver selectivity.

The circuit in FIG. 46, in some embodiments, can be a piece of a complete mixer. In the mixer the data would be multiplied onto the carrier wave. The envelope would be input on the port normally used for a constant DC current. In this embodiment, a sine wave is used instead of the constant current. In the complete mixer the data would be

multiplied onto the carrier signal in parallel to the envelope. The data input is not depicted in FIG. 46. In this embodiment, the multiplication only works when it is of a lower frequency than the carrier wave.

In another embodiment not using a mixer circuit, to reduce the side lobes each sub-band carrier would need a filter. The output would be selected after the filter. The circuit in FIG. 46 achieves the same result without multiple filters and with a single element for all carrier frequencies. The multiplier circuit eliminates the space and difficulty of using and manufacturing filters.

In other embodiments, other circuits may be used to create a sine wave envelope for the carrier. These other embodiments would also decrease the side lobes and increase the bandwidth.

When transmitting UWB signals, it may be necessary to generate a narrow pulse in order to create the ultra-wide spectrum. What follows are various techniques for isolating a single pulse cycle from a carrier wave. Previously, generating wide band signals with controlled properties was difficult. Particularly, using completely digital methods, generating a controlled pulse signal was difficult due in part to difficulty in controlling the exact rise and fall times of the signal.

FIG. 48 depicts a single monocycle extracted from a carrier wave. A carrier wave 802C is multiplied by a slow data clock 801C to isolate a group of cycles 803C. A single monocycle 804C can be isolated from the group of cycles 803C using the schemes discussed below. The resultant monocycle has many properties similar to the carrier wave and various aspects can be controlled through controlling the carrier wave 802C, such as rise and fall time and frequency.

One way of isolating the monocycle from among a group of cycles is shown in FIG. 49. The result depicted in FIG. 49 may be implemented using a stub. In FIG. 49 the

carrier 802C is multiplied by a slow data clock 801C, thereby isolating a group of cycles 803C. The resultant signal 803C is fed to a stub, which will delay the signal by one cycle 901C. The two signals 901C and 803C are combined with the result being an output of a single cycle 902C.

In one embodiment, the first switch may be implemented using a diode. The second stage may be implemented using a stub of 0.5 wavelengths with the edge connected to ground. The resultant wave 902C will have a negative residue at the end of the pulse. This can be removed by using a clock with half the required pulse frequency, where there will be a positive polarity monocycle from the rising edge of the clock and a negative polarity monocycle from the falling edge of the clock. The negative monocycle can be cancelled by multiplying every even pulse by –1. This may be done by changing the polarity of the even data bits or chips.

FIGS. 50 and 51 depict two embodiments of how carrier switching can be implemented In FIG. 50 an embodiment is shown that achieves fast carrier switching using a diode 1003C. In this embodiment, the carrier 1001C is switched on and off with a duty cycle of 50% using the diode 1003C. The signal is then passed through the stub 1004C. The data 1005C is multiplied onto the resultant signal using a mixer 1006C.

In another embodiment, shown in FIG. 51, the carrier 1101C is switched by multiplying by the clock signal with a mixer 1103C. The signal is then passed through a stub 1104C. The data 1105C is multiplied onto the resultant signal using another mixer 1106C.

FIG. 52 shows how the embodiment depicted in FIG. 51 achieves the isolation of a single monocycle. The data clock 1201C is mixed with the carrier 1202C resulting in signal 1203C. The resultant signal 1203C is fed to a stub, which will delay the signal by one cycle 1201. The two signals 1201C and 1203C are combined with the result being an output of a single cycle 1205C.

In another embodiment, similar results may be achieved using an active stub configuration depicted in FIG. 53. Using active elements enables certain embodiments to be implemented on a chip. In this embodiment the stub is replaced with a differential amplifier 1301C and a delay line 1302C. Rather than delaying the carrier, like was done in other embodiments, in this embodiment the signal by which the carrier is multiplied 1305C is delayed. The carrier 1306C is multiplied by the data clock 1305C in mixer one 1304C and the carrier is multiplied by a delayed data clock in mixer two 1303C. The two resultant signals are subtracted using the differential amplifier 1301C, which results in a signal with a single monocycle.

FIG. 54 shows the how the embodiment depicted in FIG. 53 achieves the isolation of a single monocycle. The data clock 1401C is multiplied by the carrier 1402C, resulting in the signal 1403C. The data clock 1401C is delayed and multiplied by the carrier 1402C, resulting in the signal 1404C. The subtraction of signals 1404C and 1403C results in an isolated monocycle 1405C.

In some of the embodiments the isolation of a monocycle results in monocycles appearing both positively and negatively. In example can be seen in FIG. 49 where some monocycles are positive 903C and some are negative 904C. Other examples may be seen in other embodiments. In some embodiments, this effect may be compensated for by altering the data signal that is modulated onto the carrier signal.

In other embodiments pulses may be generated using a carrierless transmission scheme.

FIG. 55 shows one embodiment of a carrierless transmitter. FIG. 56 shows the resultant signals from various elements of the embodiment in FIG. 55. The base band pulse generator 1501Cgenerates the pulse shape 1601C. Both the pulse and a delayed 1502C version of the pulse are sent to a polarity generator 1504C. The delayed version of the pulse

may be seen in 1602C. The polarity generator selects to send the two signals either through the crossed lines or the parallel lines, depending on the input data signal 1503C. The two signals are then subtracted using a differential amplifier 1505C. The inputs to the amplifier 1505C are either 1603C and 1604C; or 1606C and 1607C, depending on the data input to the polarity generator 1504C. If the inputs are 1603C and 1604C the output of the amplifier is 1605C. If the inputs are 1606C and 1607C the output of the amplifier is 1608C. The filter 1506C may be used in some embodiments to select certain frequency ranges on which the signal will be sent.

FIG. 57 depicts one embodiment of the pulse generating transmitter when transmission is accomplished using a carrier signal. The pulse generation is similar to the embodiment shown in FIG. 55, where a pulse generator sends a pulse and a delayed pulse to a polarity generator. In the embodiment in FIG. 57, rather than subtracting the pulses using a differential amplifier, a differential mixer is used. The outputs of the polarity generator 1504C are sent to the inputs of a differential mixer 1601C where they are subtracted. The second input of the differential mixer is a carrier signal 1602C, which multiplies the result of the subtraction to produce the output.

FIG. 58 shows the resultant signals at different stages of various ternary modulation schemes, including the one depicted in FIG. 57.

FIG. 59 depicts one embodiment of a way to increase the frequency of a data clock. In this embodiment a lower frequency data clock is multiplied first by a 8X multiplier 1902C and then by a 6X multiplier, which increases the frequency of the clock signal from 100 MHz to around 4.8 GHz. The pulses are modulated onto the carrier using a pulse generator 1904C and a switch 1905C. A UWB signal can be generated by switching the multiplier voltage on and off.

What follows is a discussion of scalable multi-band UWB systems and methods. In some embodiments, the present invention provides a multi-band ultra-wide band (UWB) communication system capable of adaptively and scalably supporting different applications with different requirements, as well as different desired or ideal properties relating to the communications. The various requirements or ideal properties may involve parameters such as power consumption, performance, range, and resistance to multipath interference and spectral flatness. In some embodiments, in such a system, optimizing for one parameter may include tradeoffs in other parameters. For example, an UWB communication system can require either a low range or a high range, in addition, or may call for or ideally include low power consumption or high power consumption. UWB is scalable and therefore well suited to allowing for the parameter tradeoffs. In some embodiments, multi-band UWB facilitates allowing for such parameter tradeoffs.

In some embodiments, in a multi-band UWB communications system, at least one transmission or reception parameter in a multi-band UWB communications system, such as pulse repetition frequency utilized in transmission, can be set or varied to provide the ability to tune the relevant parameters for a given application. Such transmission or reception parameters can be set according to requirements, or ideal or desired properties, for a particular application. Alternatively, such transmission and reception parameters may be varied by the system in order to adapt to varying application requirements, or ideal or desired properties. For example, in some embodiments, the transmission or reception parameters can be varied automatically by the communications system, such as by the use of an algorithm.

A scalable multi-band UWB communication system allows for tradeoffs between parameters such as complexity, power consumption, performance and bit-rate. In addition, a scalable UWB system can perform these tradeoffs while retaining the collision avoidance properties of the frequency hopping sequences.

In multi-band UWB systems that may span multiple pico-nets, it may be advantageous for each pico-net to utilize a different frequency hopping sequence. That is, the order of the bands on which each pico-net transmits is different. This technique provides advantages including avoiding collisions between signals originating from different pico-nets.

In some embodiments, in a scalable UWB system, signals may be transmitted on multiple bands using a burst symbol cycle, or discontinuous, transmission scheme. A burst symbol cycle transmission includes an ON period during which one or more symbols are transmitted, and an off period during which no signal is transmitted. Further details regarding burst symbol cycles and burst symbol cycle transmission can be found in previously incorporated by reference U.S. Application No. 10/603,372, filed on June 25, 2003. The transmission, however, viewed as a whole over the entire range of bands may appear to be continuous even though the signals being transmitted over one or more individual sub-bands may be discontinuous. Alternatively, the transmission viewed as a whole over the entire range of sub-bands may itself be discontinuous, in addition to the signal transmissions over particular sub-bands being discontinuous.

In the embodiment seen in Fig. 60, the transmitted signal 1D is comprised of various frequencies Fa, Fb, etc., yet viewed as a whole appears nearly continuous. Increasing the space between transmissions across bands by varying the pulse repetition frequency (PRF) facilitates various tradeoffs between parameters while maintaining the collision avoidance properties of the frequency hopping sequences. In Fig. 60 the transmitted signal 3D illustrates one embodiment of decreasing the PRF, where only every other signal is transmitted, thereby spacing out the signals within the entire transmission.

In some embodiments, varying the PRF can be accomplished by dropping certain transmitted signals. For example, in a pulse transmission scheme utilizing half PRF, every other pulse from the full PRF signal can be skipped. That is, if the original signal

transmits a pulse on frequencies fa, fb, fc, fd, and fe in that order; the half PRF transmission will transmit pulses only on fa, fc, and fe and remain silent for the time allocated for transmitting on fb and fd and in the next cycle pulses will be only on fb and fd. In another embodiment, the entire spectrum may be utilized with additional delay added between the same frequencies, as in Fig.60 signal 2. As in the previous example, if the full PRF transmission occurs on fa, fb, fc, fd, etc. in that order, the half PRF may utilize all the frequencies and add an additional silent time between the transmissions. The technique of varying the PRF is not limited to pulse transmissions. In other embodiments, transmissions utilizing OFDM, QPSK, or other modulation schemes may utilize and benefit from varying the PRF.

Varying the PRF impacts the bit-rate of the transmitted signal. Since signals are transmitted at a lower rate in a decreased PRF scenario, the system must adjust to maintain the same bit-rate as the full PRF scenario. In some embodiments, the system may decrease the amount of bits utilized for spreading or coding. This enables the effective bit-rate to remain the same but may impact performance. In other embodiments, the amount of coding or spreading can remain constant and the effective bit-rate will be reduced. In another embodiment, some combination of reduction of bit-rate, coding and spreading may be used to reach a desired level of bit-rate and performance.

In some embodiments, varying the PRF may be accomplished through any combination of on and off periods within the frequencies in a sequence. Half PRF, for example, may be accomplished by having an off period in every other frequency in the sequence. Alternatively, in other embodiments, half PRF could entail having two frequencies on followed by two frequencies off. Other embodiments may have other combination of on and off periods.

Varying the PRF provides advantages to the scalable UWB system. The following is a description of some of the advantages provided.

Decreasing the PRF improves the energy collection properties of the receiver. In one embodiment, a full PRF system with one receiver chain has a limited time to collect energy transmitted on a particular frequency before it is required to switch to the next frequency. To increase energy collection in a full PRF system, an additional receiver chain is needed. Increased energy collection could then be accomplished through operating each chain in parallel on alternating frequencies. With reference to Fig. 61, in a half PRF system, the transmitted signal 101D is available to the receiver chain for a longer amount of time. Therefore, for example, the energy in f1 can be collected, in the one receiver chain case 102D, until the start of the transmission of the next frequency f4.

In some embodiments, energy collection may be improved by increasing the number of receiver chains. In one embodiment, having one receiver chain per frequency will allow for longer energy collection times. In other embodiments, there may be fewer chains than the number of frequencies and the chains may need to collect energy on more than one frequency.

In some embodiments, instead of increased energy collection, the receiver chain may shut down during the quiet time, thereby reducing power consumption. In some embodiments, power consumption may also be reduced at the transmitter by shutting off during the periods between the transmitted signals.

In some embodiments, an ADC bit number, or other properties or parameters relating to transmisstion or reception, are varied based on variation in the application or variation in environmental requirements.

In some embodiments, when the symbol length is long, such as an OFDM symbol, the system may achieve greater power efficiency compared to a pulsed system. In the case of long symbols, there is less overhead for on and off switching times.

Multiband UWB itself provides some protection against inter-symbol interference (ISI). By spacing out the usage of similar frequencies, sufficient time may exist between the repetition of frequencies as to avoid ISI. In certain situations, for example, where the channel response is long, there may not be enough time between repetition of the same frequency to avoid ISI.

With reference to Fig. 62, decreasing the PRF may help mitigate ISI effects. The transmitted signal 201D repeats f1 every seven pulses. The channel effects elongate the signal seen at the receiver 202D so that received signal collides with the next signal on the same frequency. By transmitting at half PRF 203D, and spacing out the transmitted pulses, the collision at the receiver 204D is avoided.

This situation is particularly relevant to pulse transmissions where the signal transmission time is much shorter than the effects of the channel. In longer transmission schemes such as OFDM, the beneficial effects of decreased PRF can be seen in cases where transmissions on one frequency may leak into another frequency transmitted close in time. In some embodiments, reducing the PRF can mitigate the cross band inference.

Similar to the benefits achieved for ISI mitigation, variable PRF may also enable the more efficient use of notch filters. Notch filters may be used, in some embodiments, to filter out narrow-band interferers. In these embodiments, the signal may get spread out over time due to the effects of the filter, similar to channel effects that elongate the signal. Decreasing the PRF enables the receiver to better handle the effects of the notch filter.

In some embodiments, reducing the PRF increases the selectivity against narrow-band interference by increasing the integration period and/or by using equalization techniques. The increased time provided by reducing the PRF may also allow for greater frequency selectivity with the filter. The improvement, due to decreasing the PRF, may, in some embodiments, allow the filter to be implemented on chip.

In some embodiments, which use a longer symbol, such as OFDM, narrow band filtering and DC filtering may be more easily achieved.

In one embodiment the notch filter is implemented on chip and is implemented using active elements with adaptive calibration. The filter is well integrated in the receiver chain, has low attenuation, and is highly phase linear in the adjacent sub-bands.

Reducing the PRF helps, in some embodiments, mitigate the effects of multipath interference between pico-nets. In some embodiments, each pico-net utilizes a distinct frequency hopping sequence. This is done to avoid collisions when the same frequency is used by two or more pico-nets. In systems that use high pulse rate transmissions, the frequencies may get spread across a longer time due to channel effects and multipath interference.

With reference to Fig.63, transmissions are shown on two pico-nets a desired and an interferer. When there are no adverse channel or multipath effects, the interferer 301D and the desired transmission 302D may collide at only one frequency, f1. If, however, the interferer 303D is elongated due to multipath interference or channel effects, then collisions may occur in multiple frequencies, such as f1 and f2.

Decreasing the PRF, as shown in Fig. 64, mitigates the effects of the multipath interference and channel effects. Both the desired transmission 401D and the interferer 402D are transmitted with half PRF. With no channel effects or interference there is only one

potential collision, here, f1. With multipath interference on the interferer 403D, the half PRF reduces the collision so that it only affects one signal on the desired transmission 404D.

In transmission schemes that utilize longer symbols, for example, OFDM, the channel effects and multipath interference are not as relevant. Using longer symbols for each transmission may provide benefits to an ultra-wide band system, as the channel response length will become less significant compared to the symbol length. This may mitigate effects of multiple access interference and the increased symbol length may improve energy collection. Certain embodiments may use OFDM transmission for longer symbols, while other embodiments may use other transmission schemes.

In addition to aforementioned benefits, reducing the PRF reduces multiple symbol interference. In some embodiments, multiple pico-nets may be uncoordinated and will not have aligned phases. In such cases interference may occur across pico-nets in partial symbols such as half symbols or one-third symbols. Figure 65 illustrates a half collision between frequencies F1 and F3 in two pico-net transmissions 501D and 502D, where two out of three symbols may be lost. Using half PRF such collisions may be avoided. In Fig. 66 two signals, 601D and 602D, are shown. With the reduced PRF, only one symbol collision out of three is possible.

Limiting the number of collisions allows different pico-nets to operate in closer proximity to one another. Since interference between symbols is minimized, minor collisions are removed that would have disrupted transmission on near systems.

The benefits listed above present tradeoffs in parameters that may be useful in certain embodiments of the invention. In some embodiments, the system may choose how to tune the parameters and the level of PRF reduction based on levels set by the application. In other embodiments, the system may be adaptive and sense the need for certain parameters during use and change accordingly.

In some embodiments, additional scalability may be added to a multi-band UWB system by using a variable number of bits in the A/D converter. This may help decrease power consumption. In the A/D, varying the bits would use less number of bits to represent a signal. Performance may be negatively affected in such a scenario.

In order to provide for collision avoidance in scenarios with multiple pico-nets, some embodiments use different frequency hopping sequences in each pico-net. Some embodiments of multi-band ultra-wide band use frequency hopping sequences comprised of seven frequencies, as described below. In order to enable variable PRF, in some embodiments, certain frequencies in each sequence are skipped in the first cycle while the others will be skipped in a second cycle, as described above. In other embodiments, it is possible to use a variable PRF with a different sequence or to insert space between the original frequency sequence. In some embodiments, the sequence may utilize more or less than seven frequencies.

With reference to Fig. 67, a set of sequences is shown. Each sequence s1 through s6 illustrates a frequency hopping sequence that may be utilized by a pico-net. In this example, the different sequences allow for six pico-nets to operate within the same vicinity while avoiding collisions between pico-nets. The set of frequencies illustrated in Fig. 67 has the property that, regardless of how the sequences are shifted relative to one another, there will only be at most one collision where multiple pico-nets are using the same frequencies.

With reference to Fig. 68, the sequence from Fig. 67 is shown after switching to half PRF and one-third PRF. The half rate PRF and the low rate (one-third) PRF, in this embodiment, are facilitated by removing every other or leaving every third frequency, respectively. Fig. 69 shows another embodiment, where the sequences are comprised of 4 frequencies. This may be due to interference in certain bands or a limited bandwidth system.

Fig. 70 illustrates an embodiment with 14 frequencies in the sequence where each transmitter transmits on two frequencies in parallel. Other embodiment may have a different number of frequencies.

In transmitting multi-band UWB signals, some embodiments may use cyclic-prefix (CP) transmission, zero-padding (ZP) transmission or a combination of both. Embodiments that utilize OFDM transmissions may be particularly suited to use CP, ZP or both. Fig. 71 illustrates an algorithm for OFDM using CP. Fig. 72 illustrates the algorithm for OFDM using ZP. Fig. 73 illustrates an algorithm for OFDM using a combination of partial CP and ZP.

While the invention has been described and illustrated in connection with preferred embodiments, many variations and modifications as will be evident to those skilled in this art may be made without departing from the spirit and scope of the invention, and the invention is thus not to be limited to the precise details of methodology or construction set forth above as such variations and modification are intended to be included within the scope of the invention.

WHAT IS CLAIMED IS:

1. A method for transmitting information, the method comprising:

transmitting, for a first period of time of each of a series of burst symbol cycles, one or more symbols, wherein each of the symbols comprises a bit sequence, and wherein each of the bit sequences maps to one or more bits of the information; and

suspending transmission for a second period of time of each of the series of burst symbol cycles.

2. The method of claim 1, comprising continuously transmitting each of the series of burst symbol cycles.

3. The method of claim 1, comprising, after transmitting the series of burst symbol cycles:

suspending transmission for a period of time between the series and a second series; and

after suspending transmission for the period of time between the series and the second series, transmitting the second series of burst symbol cycles.

4. The method of claim 1, wherein transmitting one or more symbols comprises transmitting one or more symbols using a phase modulation technique.

5. The method of claim 1, comprising, prior to transmitting the one or more symbols, mapping the one or more bits of the information to the one or more symbols.

6. The method of claim 1, wherein transmitting the one or more symbols comprises wirelessly transmitting the one or more symbols.

7. The method of claim 1, wherein transmitting the one or more symbols comprises transmitting the one or more symbols using wired transmission.

8. The method of claim 1, wherein transmitting one or more symbols comprises transmitting a wideband signal.

9. The method of claim 1, wherein transmitting one or more symbols comprises transmitting an ultra-wide band signal.

10. The method of claim 1, comprising determining a duration of each of the first and the second periods of time to correspond with desired transmission parameters.

11. The method of claim 10, wherein determining a duration of each of the first and the second periods of time comprises determining a duration of each of the first and the second periods of time to correspond with at least one of a desired power usage, a desired duty cycle, a desired data transfer rate, a desired interference susceptibility, a desired spectral mask, a desired spectral line set, and a desired chanellisation.

12. The method of claim 10, comprising determining a duration of each of the first and the second periods of time on a burst by burst basis.

13. The method of claim 10, wherein the series of burst symbol cycles comprises a first subseries and a second subseries, and comprising varying durations of periods of transmitting and periods of suspending transmitting, between the first subseries and the second subseries.

14. The method of claim 10, comprising, prior to transmitting the first series of burst symbol cycles, continuously transmitting a plurality of bit sequences.

15. The method of claim 14, comprising continuously transmitting the plurality of bit sequences in a preamble period.

16. The method of claim 1, comprising varying a bit sequencing technique between first periods of time of the burst sequence cycles.

17. The method of claim 1, comprising selecting transmission signal polarity to control spectral shaping.

18. The method of claim 1, comprising transmitting each burst in a different frequency.

19. The method of claim 18, wherein the frequency is selected according to at least one of the information and a pseudo-random sequence.

20. The method of claim 1, comprising transmitting each burst in more than one frequency.

21. The method of claim 20, wherein the frequencies are selected according to at least one of the information and a pseudo-random sequence.

22. A method for receiving information, the method comprising:

receiving, for a first period of time of each of a series of burst symbol cycles, one or more symbols, wherein each of the symbols comprises a bit sequence, and wherein each of the bit sequences maps to one or more bits of the information; and

suspending reception for a second period of time of each of the series of burst symbol cycles.

23. The method of claim 22, comprising, after receiving the one or more symbols, mapping the one or more symbols to the one or more bits of information.

24. A method for transmitting information, the method comprising:

translating a continuous signal into a series of burst symbol cycles;

transmitting, for a first period of time of each of the series of burst symbol cycles, one or more symbols, wherein each of the symbols comprises a bit sequence, and wherein each of the bit sequences maps to one or more bits of the information; and

suspending transmission for a second period of time of each of the series of burst symbol cycles.

25. The method of claim 24, comprising continuously transmitting each of the series of burst symbol cycles.

26. The method of claim 24, comprising, after transmitting the series of burst symbol cycles:

suspending transmission for a period of time between the series and a second series; and

after suspending transmission for the period of time between the series and the second series, transmitting the second series of burst symbol cycles.

27. A method for transmitting information, the method comprising:

translating a continuous signal containing the information into a second signal containing the information, the second signal comprising a series of burst signal cycles;

transmitting, for a first period of time of each of the series of burst symbol cycles, one or more symbols, each symbol comprising a bit sequence, wherein each of the bit sequences maps to one or more bits of the information; and

suspending transmission for a second period of time of each of the series of burst symbol cycles.

28. A method for transmitting information, the method comprising:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips; and

suspending transmission for a second period of time of each of the series of burst symbol cycles.

29. The method of claim 28, wherein transmitting a plurality of chips comprises transmitting one or more burst symbol cycles per one or more bits of the information.

30. The method of claim 28, wherein transmitting a plurality of chips comprises transmitting a plurality of chips using a direct sequence spread spectrum transmission technique comprising combining one or more pseudorandom sequences with a plurality of information bit sequences.

31. The method of claim 30, comprising utilizing a single pseudorandom bit sequence in transmitting every bit of the information.

32. The method of claim 28, wherein transmitting a plurality of chips comprises transmitting a plurality of chips using a binary phase shift keying modulation technique.

33. An ultra-wide band based wireless communication system, the system comprising:

a transmitter for:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, one or more symbols, wherein each of the symbols comprises a bit sequence, and wherein each of the bit sequences maps to one or more bits of the information; and

suspending transmission for a second period of time of each of the series of burst symbol cycles; and

a receiver for receiving the transmitted symbols.

34. An ultra-wide band based wireless communication system, the system comprising:

a transmitter for:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips; and

suspending transmission for a second period of time of each of the series of burst symbol cycles; and

a receiver for receiving the transmitted chips.

35. An ultra-wide band based wireless communication apparatus, the apparatus comprising:

a transmitter for:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips; and

suspending transmission for a second period of time of each of the series of burst symbol cycles; and

a receiver for receiving the transmitted chips.

36. A system for ultra-wide band based communication between digital devices, the system comprising:

a first digital device comprising a first transmitter and a first receiver;

a second digital device comprising a second transmitter and a second receiver,

wherein the first and the second transmitters and the first and the second receivers facilitate communication between the first and the second digital devices, and wherein the first and the second transmitters are for:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips; and

suspending transmission for a second period of time of each of the series of burst symbol cycles; and

wherein the first and the second receivers are for receiving the transmitted chips.

37. The system of claim 36, wherein the system facilitates communication between each of three or more digital devices using burst symbol cycle transmission and reception.

38. The system of claim 36, wherein the first and second digital devices are at least part of a first cell, and wherein the system comprises a second cell, the second cell comprising:

a third digital device comprising a third transmitter and a third receiver;

a fourth digital device comprising a fourth transmitter and a fourth receiver,

wherein the third and the fourth transmitters and the third and the fourth receivers facilitate communication between the third and the fourth digital devices, and wherein the third and the fourth transmitters are for:

transmitting, using an ultra-wide band signal, for a first period of time of each of a series of burst symbol cycles, a plurality of chips; and

suspending transmission for a second period of time of each of the series of burst symbol cycles; and

wherein the third and the fourth receivers are for receiving the transmitted chips.

39. A method for transmitting information, the method comprising:

means for transmitting, for a first period of time of each of a series of burst symbol cycles, one or more symbols, wherein each of the symbols comprises a bit sequence, and wherein each of the bit sequences maps to one or more bits of the information; and

means for suspending transmission for a second period of time of each of the series of burst symbol cycles.

40. A method for transmitting information, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum; and

sending an ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising sending a signal over each of the plurality of sub-bands.

41. The method of claim 40, comprising wirelessly sending the ultra-wide band transmission.

42. The method of claim 40, wherein sending the signals comprises sending pulsed signals.

43. The method of claim 40, wherein sending the signals comprises sending burst symbol cycle transmissions.

44. The method of claim 43, wherein each burst comprises sequenced bits of information.

45. The method of claim 43, wherein each burst comprises symbols, and wherein each symbol comprises a sequence that maps to one or more bits of information.

46. The method of claim 40, wherein sending the signals comprises sending a different waveform over each sub-band.

47. The method of claim 46, wherein each of the different waveforms is used to represent different information.

48. The method of claim 40, wherein sending the signals comprises sending more than one waveform over a single sub-band at a given time.

49. The method of claim 40, wherein sending the signals comprises sending substantially identical waveforms over each of several of the sub-bands.

50. The method of claim 40, wherein sending the ultra-wide band signal comprises transmitting over only a single sub-band at a given time.

51. The method of claim 50, wherein sending the ultra-wide band signal comprises switching between different sub-bands.

52. The method of claim 51, wherein the switching is performed after each symbol is transmitted.

53. The method of claim 51, wherein the switching is performed after several symbols are transmitted.

54. The method of claim 51, wherein the switching is performed after one or more symbols are transmitted and an OFF period.

55. The method of claim 40, comprising allocating one or more of the sub-bands based on information to be transmitted.

56. The method of claim 40, comprising allocating one or more of the sub-bands based on a pseudo-random sequence.

57. A method for receiving information, the method comprising:

allocating, for signal reception, each of a plurality of frequency sub-bands of an ultra-wide band spectrum; and

receiving an ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising receiving a signal over each of the plurality of sub-bands.

58. The method of claim 57, wherein receiving the signals comprises receiving the ultra-wide band transmission and tracking the signal timing using the relation between the sub-bands phases and the signal timing.

59. The method of claim 58, wherein tracking the timing comprises tracking the sub-bands phases using a single radio chain.

60. The method of claim 57, wherein receiving the signals comprises receiving burst symbol cycle transmissions.

61. The method of claim 40, comprising transmitting information at a bit rate of 100 MBPS or higher.

62. A method for communicating information, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum;

sending an ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising sending a signal over each of the plurality of sub-bands; and

receiving the ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising receiving the signals.

63. The method of claim 62, wherein sending the signals comprises sending burst symbol cycle transmissions.

64. The method of claim 63, wherein the OFF period is used to reduce power consumption in the receiver and transmitter.

65. The method of claim 62, wherein allocating the sub-bands comprising allocating sub-bands that at least partially overlap.

66. The method of claim 62, wherein sending the signals comprises generating the signals using an analog technique.

67. The method of claim 62, wherein sending the signals comprises generating the signals using a digital technique.

68. The method of claim 62, wherein sending the ultra-wide band signal comprises:

converting a first data signal containing information into one or more encoded signals using an Inverse Fast Fourier Transform; and

converting the encoded signal into an encoded ultra-wide band signal comprising burst symbol cycles.

69. The method of claim 68, wherein sending the signals comprises sending a different waveform over each sub-band.

70. The method of claim 68, wherein sending the signals comprises sending more than one waveform over a single sub-band at a given time.

71. The method of claim 68, wherein sending the ultra-wide band signal comprises transmitting over only a single one of the sub-bands at a given time.

72. The method of claim 68 wherein sending the ultra-wide band signal comprises switching between sub-bands.

73. The method of claim 72, wherein the switching is performed after each symbol is transmitted.

74. The method of claim 72, wherein the switching is performed after several symbols are transmitted.

75. The method of claim 72, wherein the switching is performed after one or more symbols are transmitted and an OFF period.

76. The method of claim 75, wherein the OFF period is used to reduce power consumption in the receiver and transmitter.

77. The method of claim 68, comprising using a narrowband signal comprising an OFDM signal with a cyclic prefix.

78. The method of claim 68, comprising using a narrowband signal comprising an OFDM signal with at least one of a gap and a cyclic prefix.

79. The method of claim 68, comprising performing energy collecting and/or inter carrier interference mitigation by at least one of using parallel receivers, providing a gap between the OFDM symbols, cyclic prefix and using the tail of the symbol generated by multi-path in the channel.

80. The method of claim 62, wherein sending the ultra-wide band signal comprises:

converting a first data signal containing information into one or more encoded signals using an Inverse Fast Fourier Transform; and

converting the encoded signal into an encoded pulsed ultra-wide band signal.

81. The method of claim 80, wherein sending the signals comprises sending a different waveform over each sub-band.

82. The method of claim 80 wherein sending the signals comprises sending more than one waveform over a single sub-band at a given time.

83. The method of claim 80, wherein sending the ultra-wide band signal comprises transmitting over only a single one of the sub-bands at a given time.

84. The method of claim 80 wherein sending the ultra-wide band signal comprises switching between sub-bands in which pulses are transmitted.

85. The method of claim 84, wherein the switching is performed after each symbol is transmitted.

86. The method of claim 84, wherein the switching is performed after several symbols are transmitted.

87. The method of claim 84, wherein the switching is performed after one or more symbols are transmitted and an OFF period.

88. The method of claim 87, wherein the OFF period is used to reduce power consumption in the receiver and transmitter.

89. The method of claim 80, wherein the narrowband signal comprises an OFDM signal with a cyclic prefix.

90. The method of claim 80, wherein the narrowband signal comprises an OFDM signal with a gap and/or cyclic prefix.

91. The method of claim 80, comprising performing energy collecting and/or inter carrier interference mitigation by at least one of using parallel receivers, providing a gap between the OFDM symbols, cyclic prefix and using the tail of the symbol generated by multi-path in the channel.

92. The method of claim 80, comprising determining a bandwidth of each of a plurality of bands used by the second signal by a narrow pulse width.

93. A system for communicating information, the system comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands of an ultra-wide band spectrum;

a transmitter for sending an ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising sending a signal over each of the plurality of sub-bands; and

a receiver for receiving the ultra-wide band transmission comprising the information over the ultra-wide band spectrum, comprising receiving the signals.

94. The system of claim 93, wherein sending the signals comprises sending burst symbol cycle transmissions.

95. A method for communicating information, comprising:

converting a first data signal containing information into an encoded signal using an Inverse Fast Fourier Transform;

converting the encoded signal into an encoded ultra-wide band signal comprising burst symbol cycles; and

decoding the encoded ultra-wide band signal using a Fast Fourier Transform to obtain the information.

96. A method for communicating information, comprising:

converting a first data signal containing information into an encoded signal using an Inverse Fast Fourier Transform;

converting the encoded signal into an encoded pulsed ultra-wide band signal; and

decoding the encoded pulsed ultra-wide band signal using a Fast Fourier Transform to obtain the information.

97. A method for transmitting information, the method comprising:

after modulation of a narrowband signal, translating the narrowband signal containing the information into a second signal containing the information, the second signal being a wider band signal than the narrowband signal, and the narrowband signal and the second signal comprising the same modulated waveform.

98. The method of claim 97, wherein the method is used in generating a single band ultra-wide band signal.

99. The method of claim 97, wherein the method is used in generating a sub-band of a multiband ultra-wide band signal.

100. The method of claim 99, comprising transmitting for a first period of time of each of a series of burst symbol cycles, one or more bits of the information, and comprising suspending transmission for a second period of time of each of the series of burst symbol cycles.

101. The method of claim 100, wherein transmitting one or more bits of the information comprises transmitting one or more bits of the information using a carrier based signal.

102. The method of claim 100, wherein transmitting one or more bits of the information comprises transmitting one or more bits of the information using a carrierless signal.

103. The method of claim 100, comprising, during a second period of time of each of the series of cycles, transmitting information, and wherein each of the series of cycles consists of the first period and the second period.

104. The method of claim 100, comprising, during a second period of time of each of the series of cycles, re-transmitting at least one of the one or more bits of the information.

105. The method of claim 100, comprising, during a second period of time of each of the series of cycles, transmitting information other than the information contained by the narrowband signal.

106. The method of claim 97, wherein the narrowband signal comprises an OFDM signal with a cyclic prefix.

107. The method of claim 97, wherein the narrowband signal comprises an OFDM signal with a gap and/or cyclic prefix.

108. A method for transmitting information, the method comprising: transmitting, for a first period of time of each of a series of cycles, one or more bits of the information at a faster rate than a rate at which the one or more bits information would be transmitted if the one or more bits of information were transmitted using the narrowband signal.

109. The method of claim 108, wherein translating a narrowband signal into a second signal comprises widening the narrowband signal to form a widened signal and then multiplying the widened signal by a burst symbol cycle signal.

110. The method of claim 108, comprising translating a narrowband signal into a second signal, and wherein translating the narrowband signal into the second signal comprises multiplying the narrowband signal by a carrier based signal.

111. The method of claim 108, comprising translating a narrowband signal into a second signal, and wherein translating the narrowband signal into the second signal comprises multiplying the narrowband signal by a carrierless signal.

112. The method of claim 108, comprising translating a narrowband signal into a second signal, and wherein translating the narrowband signal into the second signal comprises translating the narrowband signal into an ultra-wide band signal.

113. A method for transmitting information, the method comprising translating a narrowband signal into a second signal by multiplying the narrowband signal by a wideband burst symbol cycle signal.

114. The method of claim 113, wherein the narrowband signal comprises an OFDM signal with a cyclic prefix.

115. The method of claim 113, wherein the narrowband signal comprises an OFDM signal with a gap and/or cyclic prefix.

116. The method of claim 113, comprising determining a bandwidth of each of a plurality of bands used by the second signal by a narrow pulse width.

117. The method of claim 113, wherein translating a narrowband signal into a second signal comprises multiplying the narrowband signal by a carrier based signal.

118. The method of claim 113, wherein translating a narrowband signal into a second signal comprises multiplying the narrowband signal by a carrierless signal.

119. The method of claim 113, wherein translating a narrowband signal into a second signal comprises translating the narrowband signal into an ultra-wide band signal.

120. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands; and

sending an ultra-wide band transmission comprising the information by transmitting a burst symbol cycle signal over each of the plurality of frequency sub-bands.

121. The method of claim 120, comprising sending at least two of the burst symbol cycle signals serially.

122. The method of claim 120, comprising sending at least two of the burst symbol cycles in parallel.

123. The method of claim 120, comprising switching off power to at least one circuit during OFF periods of a transmission to decrease power consumption.

124. The method of claim 123, comprising maintaining signal frequency and phase from an end of an ON period to a beginning of the following ON period.

125. The method of claim 123, comprising maintaining signal frequency from an end of an ON period to a beginning of the following ON period.

126. The method of claim 123, comprising utilizing at least one of an analog wave generator, digital wave generator, and a combination analog and digital wave generator.

127. A fast switching frequency generator for facilitating generation of a multi-band ultra-wide band transmission, the generator comprising a circuit, the circuit comprising:

at least one voltage controlled oscillator;

at least one divider;

wherein the at least one voltage controlled oscillator is adapted for use in generating a signal of a particular center frequency, and wherein the at least one divider is adapted for use in facilitating generation of multiple transmission frequency bands of the multi-band ultra-wide band transmission by outputting, from an input signal of a particular center frequency, signals of different frequency multiples of a step frequency.

128. The method of claim 127, comprising using QPSK modulation, and comprising multiplying an input signal with a data signal prior to generating signals of different frequency multiples of a step frequency.

129. A method for facilitating transmission of information using ultra-wide band transmission, the method comprising:

generating a first digital signal for use in an ultra-wide band transmission; and

substantially removing at least one harmonic from the first digital signal by subtracting, from the first digital signal, a second digital signal that is a delayed form of the first digital signal, to produce a third digital signal that is of substantially the same frequency as the first digital signal but that substantially does not include at least one harmonic included in the first digital signal.

130. The method of claim 129, wherein the subtracting comprises using differential inputs to a switch mixer.

131. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands; and

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands;

wherein phase continuity is maintained by:

dividing each of the frequency sub-bands into a plurality of segments; and

cycling transmission between segments of each of the sub-bands.

132. The method of claim 131, comprising cycling transmission between segments of each of the frequency sub-bands to produce a signal of substantially uninterrupted phase.

133. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands; and

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands, comprising producing at least one analog carrier wave of a frequency sub-band using outputs from a plurality of digital to analog converters.

134. The method of claim 133, wherein producing the at least one analog carrier wave comprises each of the digital to analog converters outputting a portion of the analog carrier wave based on an input bit, and comprises cycling through input values to produce consecutive segments of the analog carrier wave.

135. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands; and

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands, comprising using a sine wave envelope to reduce side lobes in at least one carrier frequency, comprising multiplying a signal by a sine wave of a lower frequency than the carrier frequency.

136. The method of claim 135, comprising varying pulse bandwidth while pulse repetition frequency remains constant, to facilitate control of signal spectrum characteristics and receiver selectivity.

137. A method for facilitating transmission of information using ultra-wide band transmission, the method comprising:

generating at least one carrier wave for use in an ultra-wide band transmission; and

isolating a single monocycle from the carrier wave by:

producing a first signal that is a delayed form of the carrier wave; and

combining the carrier wave with the first signal to isolate a single monocycle.

138. The method of claim 137, comprising producing a first signal that is a delayed form of the carrier wave by at least one of multiplying the carrier wave by a clock signal and switching the carrier wave using a mixer.

139. The method of claim 137, comprising feeding a signal to a stub for producing a first signal that is a delayed form of the carrier wave.

140. A method for facilitating transmission of information using ultra-wide band transmission, the method comprising :

generating a narrow-band pulse signal for use in an ultra-wide band transmission, comprising:

generating a first pulse signal;

producing a second pulse signal that is a delayed form of the first pulse signal; and

using a differential amplifier, subtracting the first pulse signal from the second pulse signal to produce the narrow-band pulse signal.

141. The method of claim 140, comprising using a polarity generator to determine which of the first and second pulse signals is to be the positive input and which of the first and second pulses is to be the negative input to the differential amplifier, based on information to be transmitted.

142. A method for facilitating transmission of information, the method comprising: generating an ultra-wide band signal, comprising:

generating a first ultra-wide band carrier signal;

combining the first carrier signal with a sine wave envelope to generate a first combined signal with reduced side lobes relative to the first carrier signal;

combining the first combined signal with an information signal to generate a second combined signal; and

transmitting the second combined signal as at least part of a multi-band ultra-wide band transmission.

143. A method for facilitating transmission of information, the method comprising: generating an ultra-wide band signal, comprising:

combining an information signal with a sine wave envelope to generate a first combined signal;

combining the first combined signal with a generated carrier signal to generate a second combined signal with reduced side lobes relative to the generated carrier signal; and

transmitting the second combined signal as at least part of a multi-band ultra-wide band transmission.

144. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands; and

allowing variation of at least one transmission parameter to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

145. The method of claim 144, comprising allowing variation of pulse repetition frequency.

146. The method of claim 144, wherein sending an ultra-wide band transmission comprises sending a burst symbol cycle transmission.

147. The method of claim 144, comprising sending a burst symbol cycle signal over each of the frequency sub-bands.

148. The method of claim 147, wherein sending an ultra-wide band transmission comprises sending a burst symbol cycle transmission.

149. The method of claim 144, comprising allowing variation of at least one transmission parameter in order to adapt to varying application requirements.

150. The method of claim 149, comprising automatically varying at least one transmission parameter in order to adapt to at least one of varying application requirements and environment requirements.

151. The method of claim 149, comprising using one or more algorithms to facilitate varying at least one transmission parameter in order to adapt to at least one of varying application requirements and environment requirements.

152. The method of claim 144, wherein sending an ultra-wide band transmission comprises using orthogonal frequency division multiplexing, and comprises using at least one of cyclic prefix transmission, zero padding, and a combination of cyclic prefix transmission and zero padding.

153. The method of claim 144, comprising allowing variation in time spreading, while sending identical information multiple times in a single sub-band as well as in different sub-bands.

154. A method for receiving information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

receiving an ultra-wide band transmission comprising the information by receiving signals transmitted over each of the plurality of frequency sub-bands; and

allowing variation of at least one of one or more reception parameters to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

155. The method of claim 154, comprising allowing variation of received pulse repetition frequency.

156. The method of claim 155, comprising reducing power consumption by shutting off the receiver at least one of during off periods, during anticipated redundant symbols, and during anticipated noisy symbols.

157. The method of claim 154, comprising varying an ADC bit number based on variation in at least one of an application and environmental requirements.

158. The method of claim 154, wherein receiving an ultra-wide band transmission comprises receiving a burst symbol cycle transmission.

159. The method of claim 154, comprising receiving burst symbol cycle signals over each of the frequency sub-bands.

160. The method of claim 159, wherein receiving an ultra-wide band transmission comprises receiving a burst symbol cycle transmission.

161. A method for communicating information using ultra-wide band transmission and reception, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands;

receiving an ultra-wide band transmission comprising the information by receiving signals transmitted over each of the plurality of frequency sub-bands; and

allowing variation of at least one of one or more transmission parameters and one or more reception parameters to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

162. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands; and

setting at least one transmission parameter to facilitate a desired trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

163. The method of claim 162, comprising setting pulse repetition frequency.

164. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands; and

varying pulse repetition frequency to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, resistance to multiple access interference, and resistance to multipath interference and spectral flatness.

165. The method of claim 164, wherein varying pulse repetition frequency comprises varying of spacing of frequencies in a sequence.

166. The method of claim 164, wherein varying pulse repetition frequency comprises replacing selected frequencies in a sequence with off periods.

167. The method of claim 164, wherein pulse repetition frequency is varied according to at least one of a particular application and a particular environment.

168. The method of claim 164, comprising adaptively varying pulse repetition frequency according to at least one of varying application requirements and varying environmental requirements.

169. The method of claim 164, comprising adaptively varying pulse repetition frequency using one or more algorithms.

170. The method of claim 164, comprising adaptively varying pulse repetition frequency

171. The method of claim 164, comprising reducing pulse repetition frequency to increase filter selectivity.

172. The method of claim 170, wherein reducing pulse repetition frequency to increase notch filter selectivity allows a chip implementation of one or more filters.

173. The method of claim 164, comprising varying pulse repetition frequency of pulse transmission.

174. The method of claim 164, comprising varying pulse repetition frequency of OFDM transmission.

175. The method of claim 174, comprising varying pulse repetition frequency to reduce cross-band interference.

176. The method of claim 164, comprising reducing pulse repetition frequency to mitigate interference between two or more pico-nets that each use a different frequency hopping sequence.

177. The method of claim 176, comprising reducing pulse repetition frequency by removing selected frequencies in a sequence and replacing them with off periods.

178. The method of claim 177, comprising reducing pulse repetition frequency by a factor of two by removing one out of every two consecutive frequencies.

179. The method of claim 177, comprising reducing pulse repetition frequency by a factor of three by removing one out of every three consecutive frequencies.

180. The method of claim 164, comprising using different frequency hopping sequences for each of multiple pico-nets.

181. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands; and

setting pulse repetition frequency to mitigate inter-symbol interference.

182. A method for transmitting information using ultra-wide band transmission, the method comprising:

allocating, for signal transmission, each of a plurality of frequency sub-bands;

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of the plurality of frequency sub-bands; and

allowing variation of pulse repetition frequency to facilitate trade-off between at least two of power consumption, energy collection, bit rate, performance, range, and resistance to multipath interference and spectral flatness.

183. A system for communicating information using ultra-wide band transmission and reception, the system comprising:

a transmitter for:

sending an ultra-wide band transmission comprising the information by transmitting a signal over each of a plurality of frequency sub-bands; and

a receiver for:

receiving an ultra-wide band transmission comprising the information by receiving signals transmitted over each of a plurality of frequency sub-bands;

wherein the system allows for at least one of selection of and variation of at least one of one or more transmission parameters and one or more reception parameters to provide adaptive trade-off between at least two of power consumption, bit rate, performance, range, and resistance to multipath interference and spectral flatness.

Fig. 1

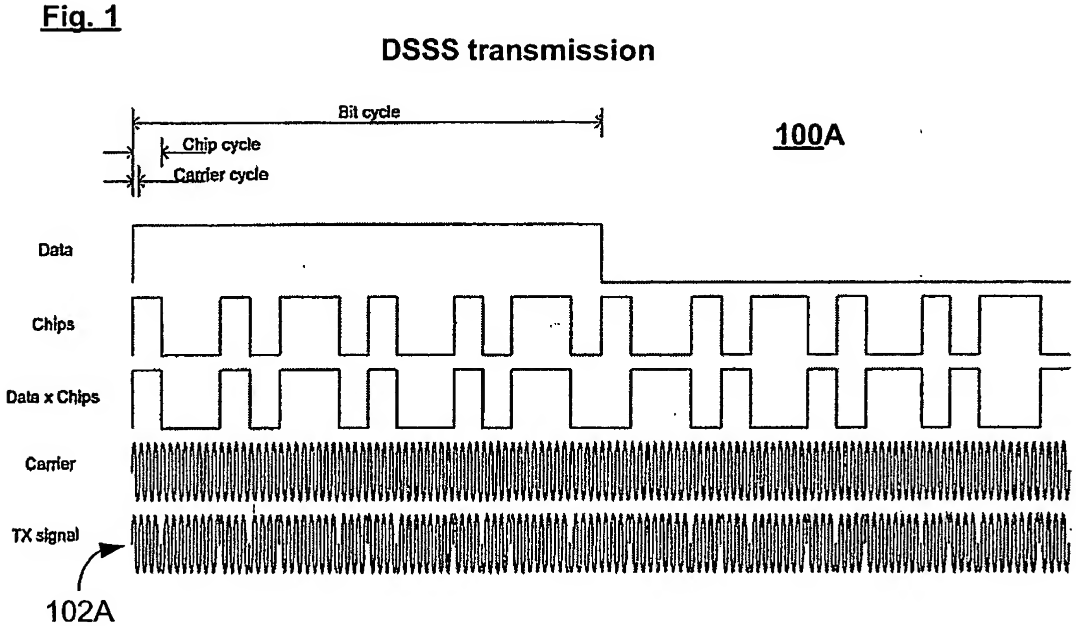

DSSS transmission
Bit cycle
Chip cycle
Carrier cycle
100A
Data
Chips
Data x Chips
Carrier
TX signal
102A

Fig. 2

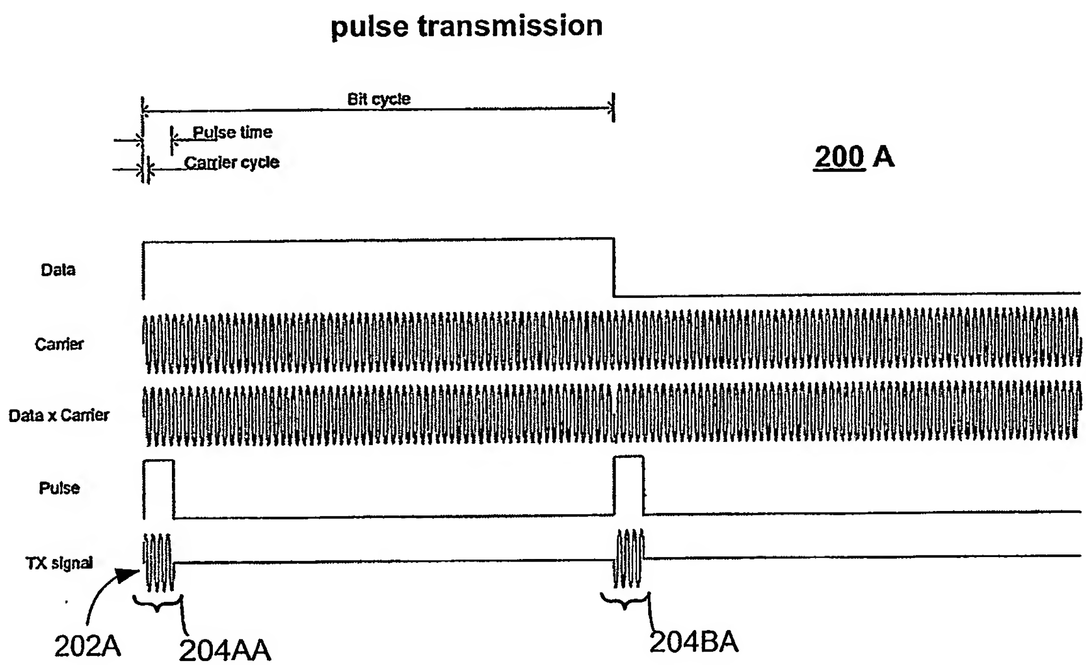

pulse transmission
Bit cycle
Pulse time
Carrier cycle
200 A
Data
Carrier
Data x Carrier
Pulse
TX signal
202A
204AA
204BA

Fig. 3

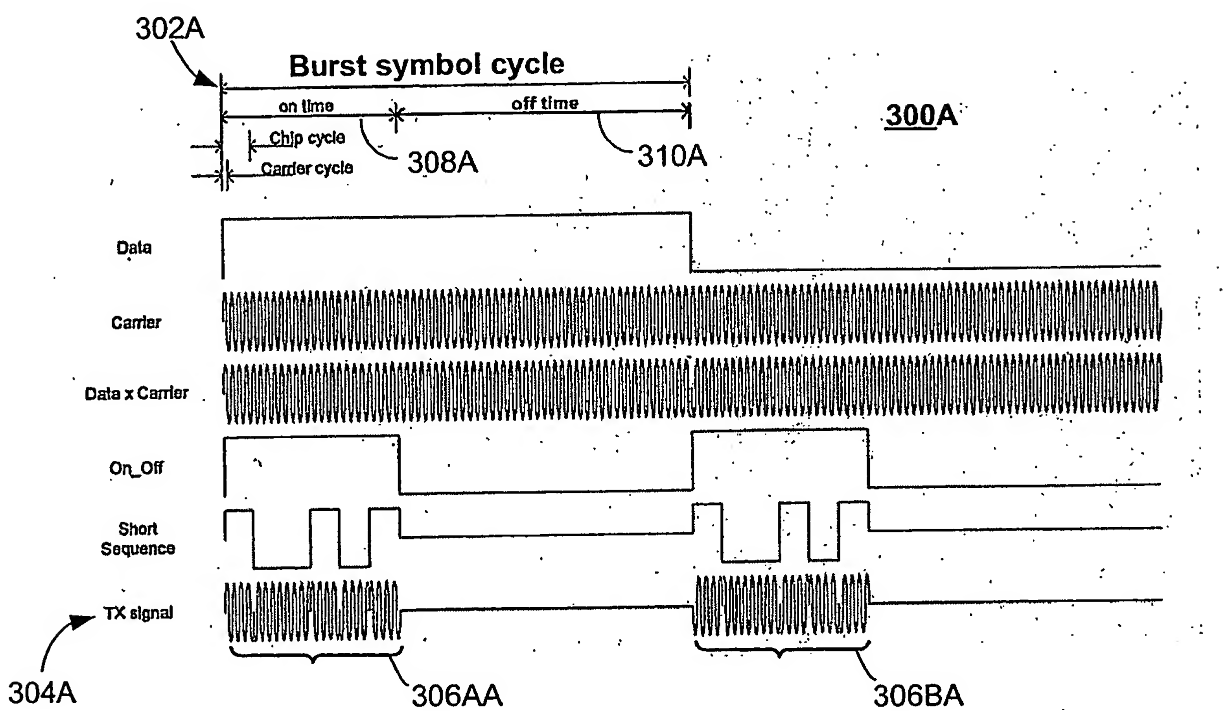

302A
Burst symbol cycle
on time
off time
300A
Chip cycle
Carrier cycle
308A
310A
Data
Carrier
Data x Carrier
On_Off
Short Sequence
TX signal
304A
306AA
306BA

Fig. 4

400A

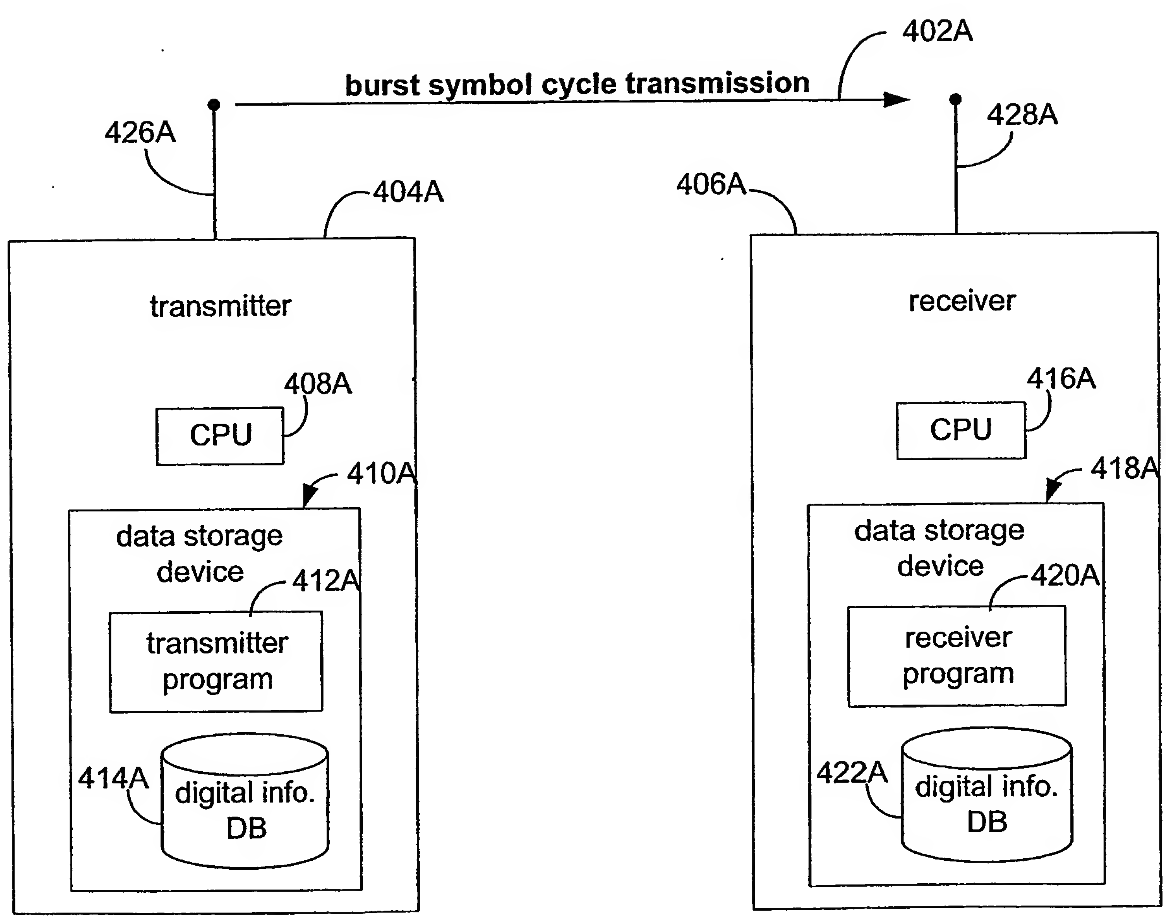
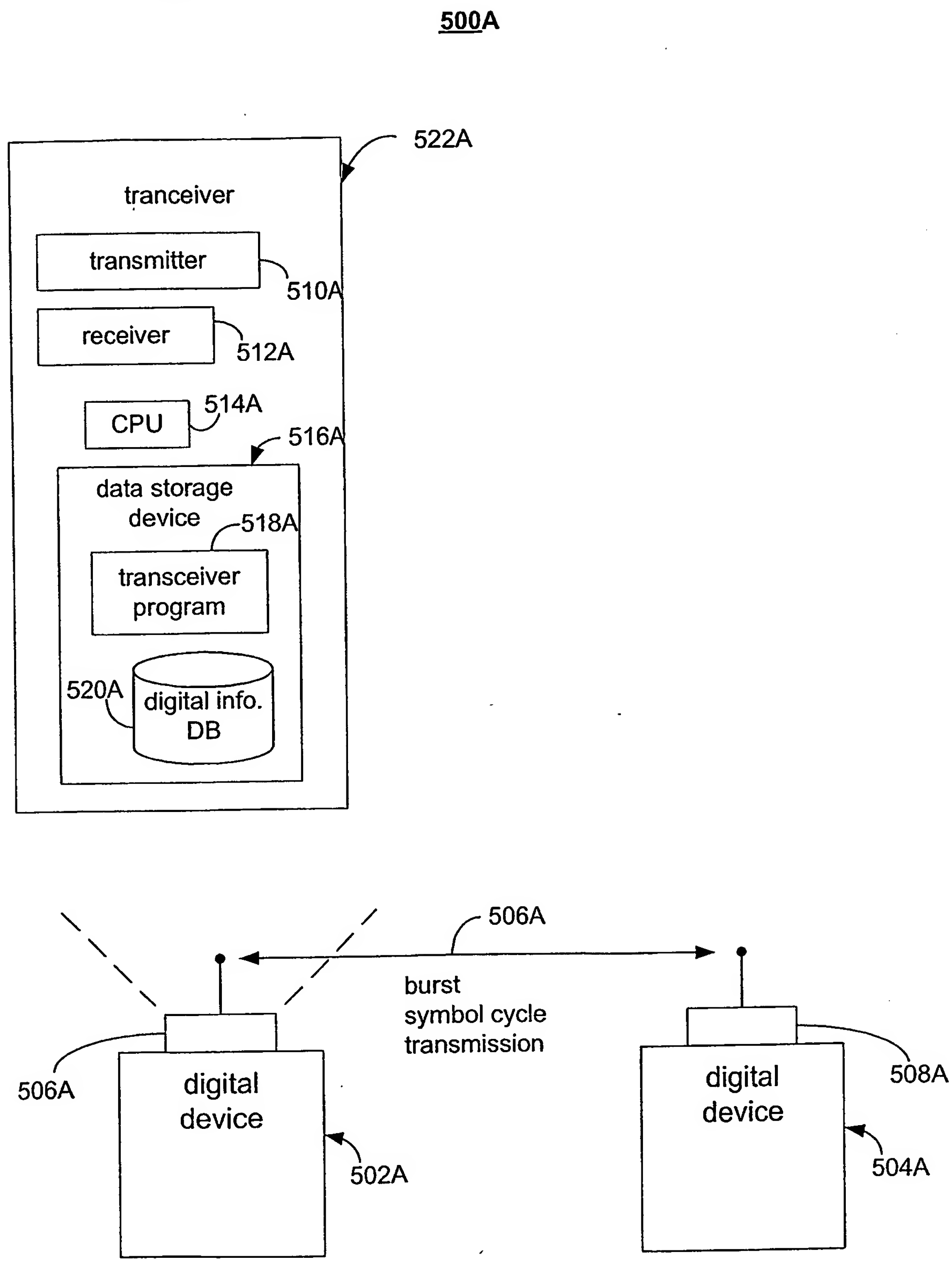

402A
burst symbol cycle transmission
426A
428A
404A
406A
transmitter
receiver
408A
CPU
416A
CPU
410A
418A
data storage device
412A
transmitter program
data storage device
420A
receiver program
414A
digital info. DB
422A
digital info. DB

Fig. 5


500A
522A
tranceiver
transmitter
510A
receiver
512A
CPU
514A
516A
data storage device
518A
transceiver program
520A
digital info. DB
506A
burst
symbol cycle
transmission
506A
digital device
502A
digital device
508A
504A

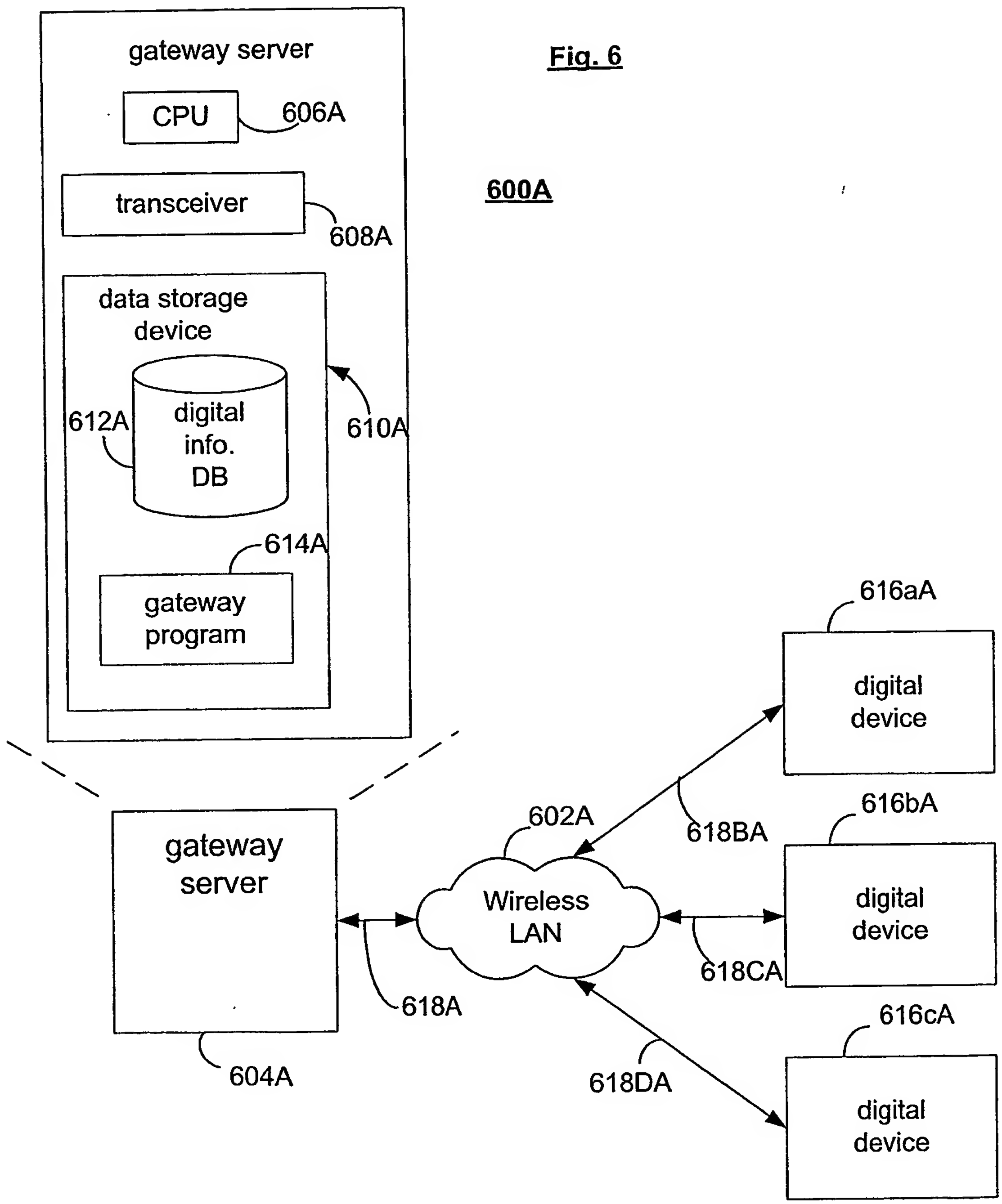


Fig. 6
600A
gateway server
CPU
606A
transceiver
608A
data storage device
digital info. DB
612A
610A
614A
gateway program
gateway server
604A
618A
Wireless LAN
602A
618BA
618CA
618DA
616aA
digital device
616bA
digital device
616cA
digital device

Fig. 7

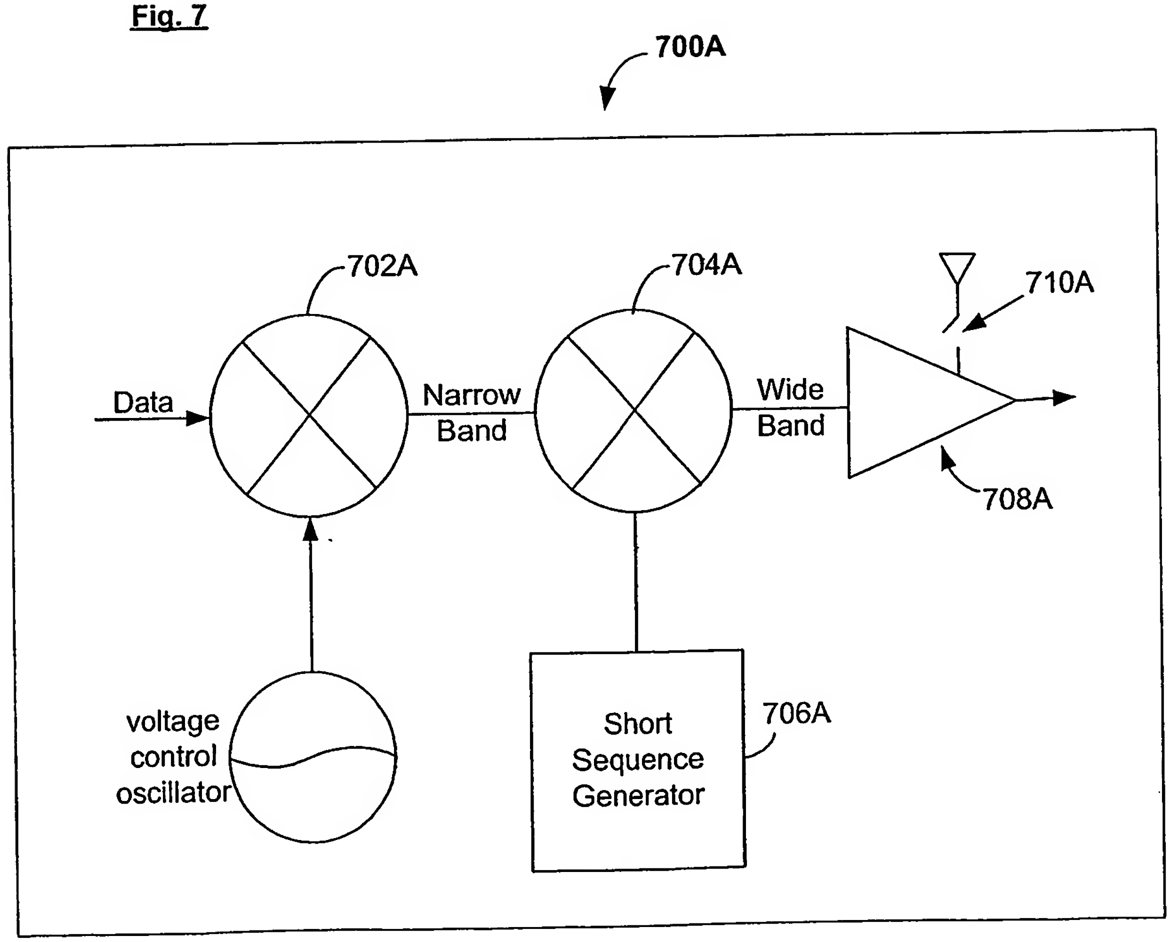

700A
702A
704A
710A
Data
Narrow Band
Wide Band
708A
voltage control oscillator
Short Sequence Generator
706A

Fig. 8

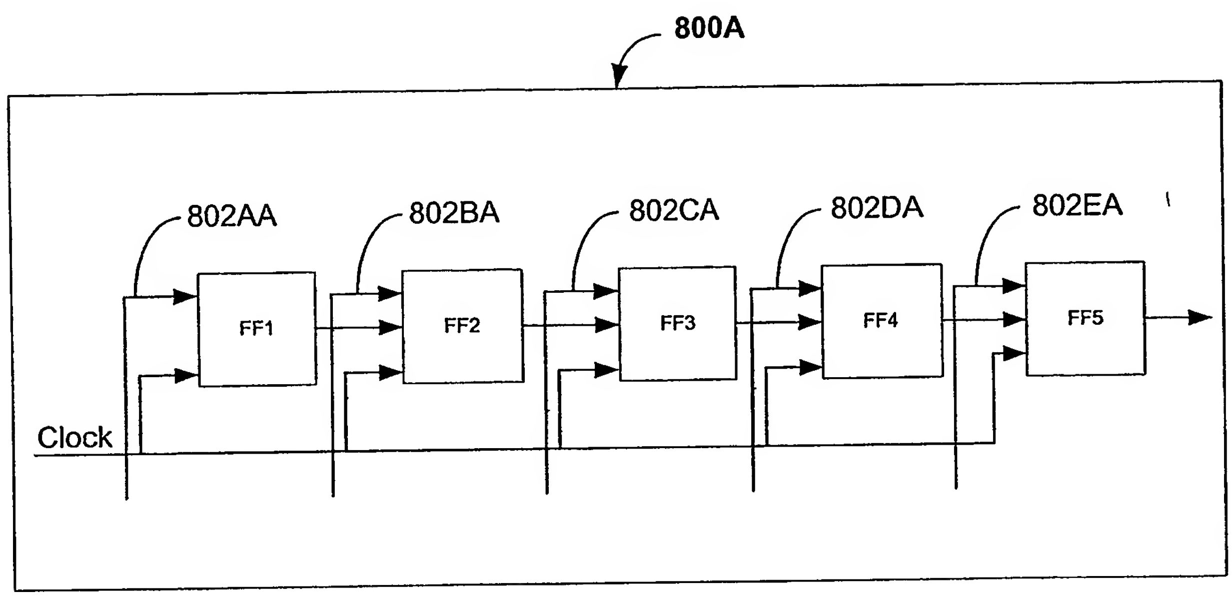


Fig. 9

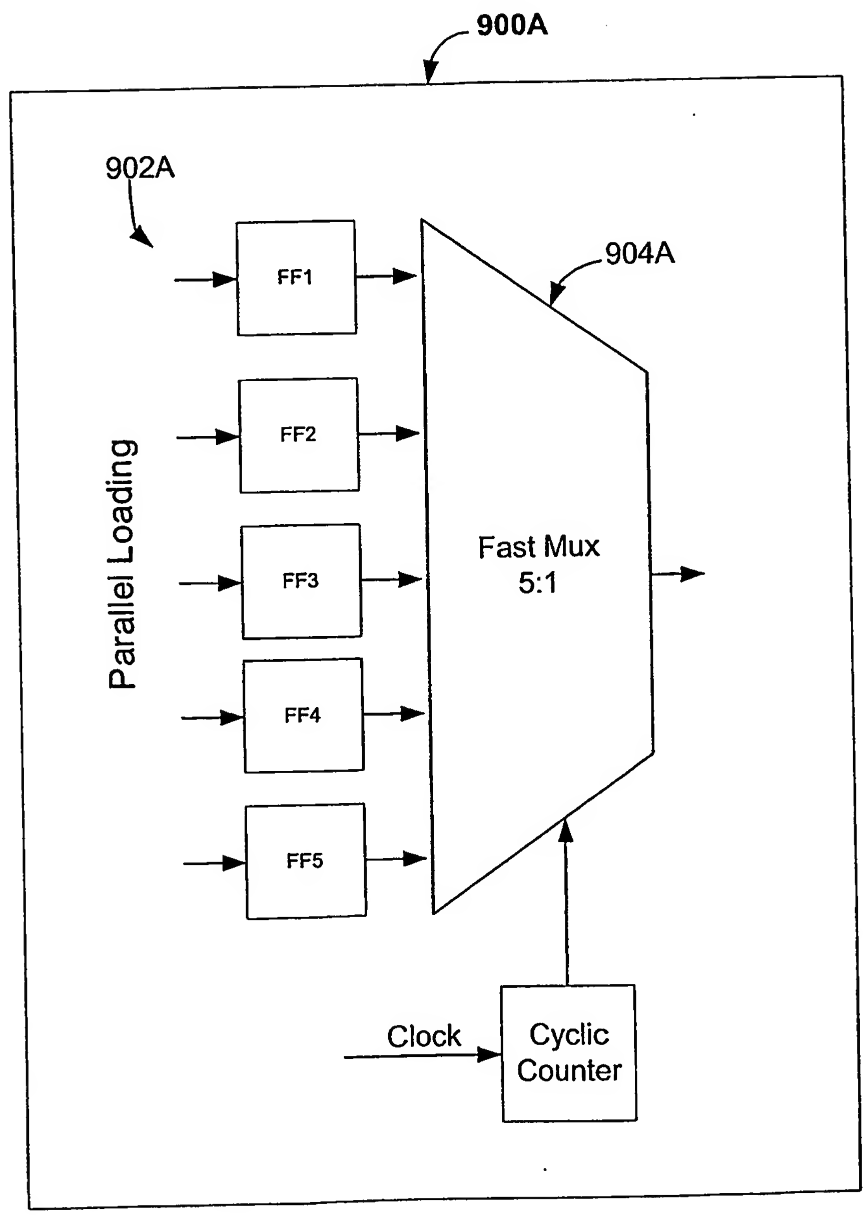

900A
902A
904A
Parallel Loading
FF1
FF2
FF3
FF4
FF5
Fast Mux
5:1
Clock
Cyclic
Counter

Fig. 10

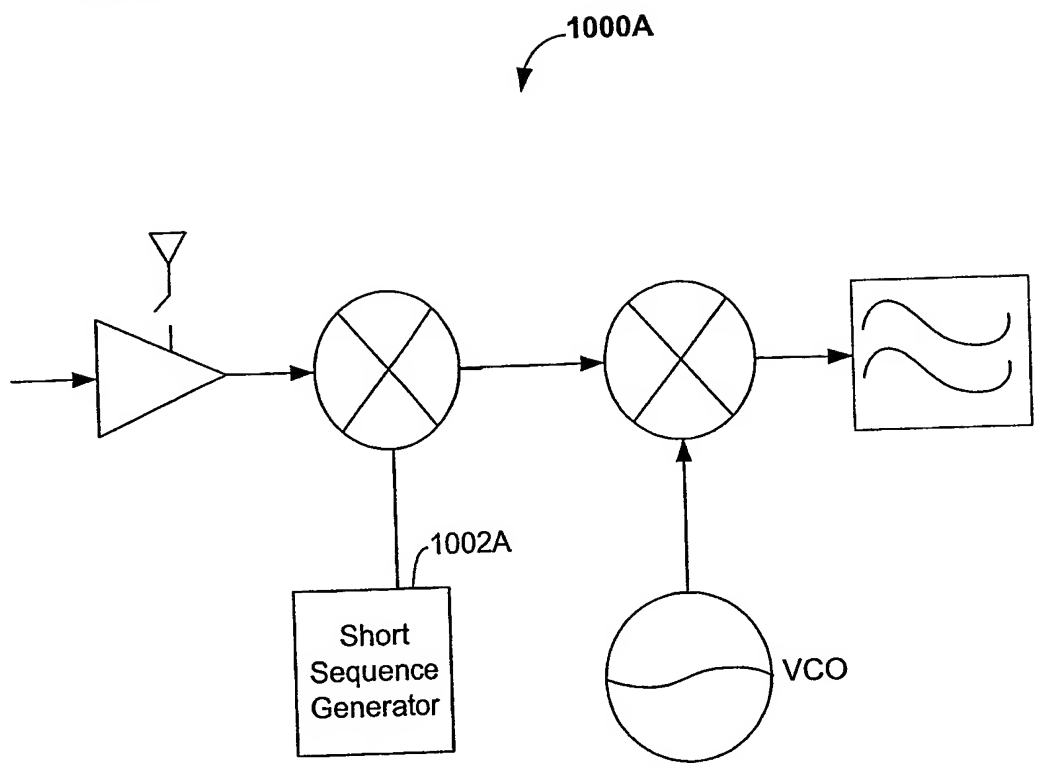


Fig. 11 1100A

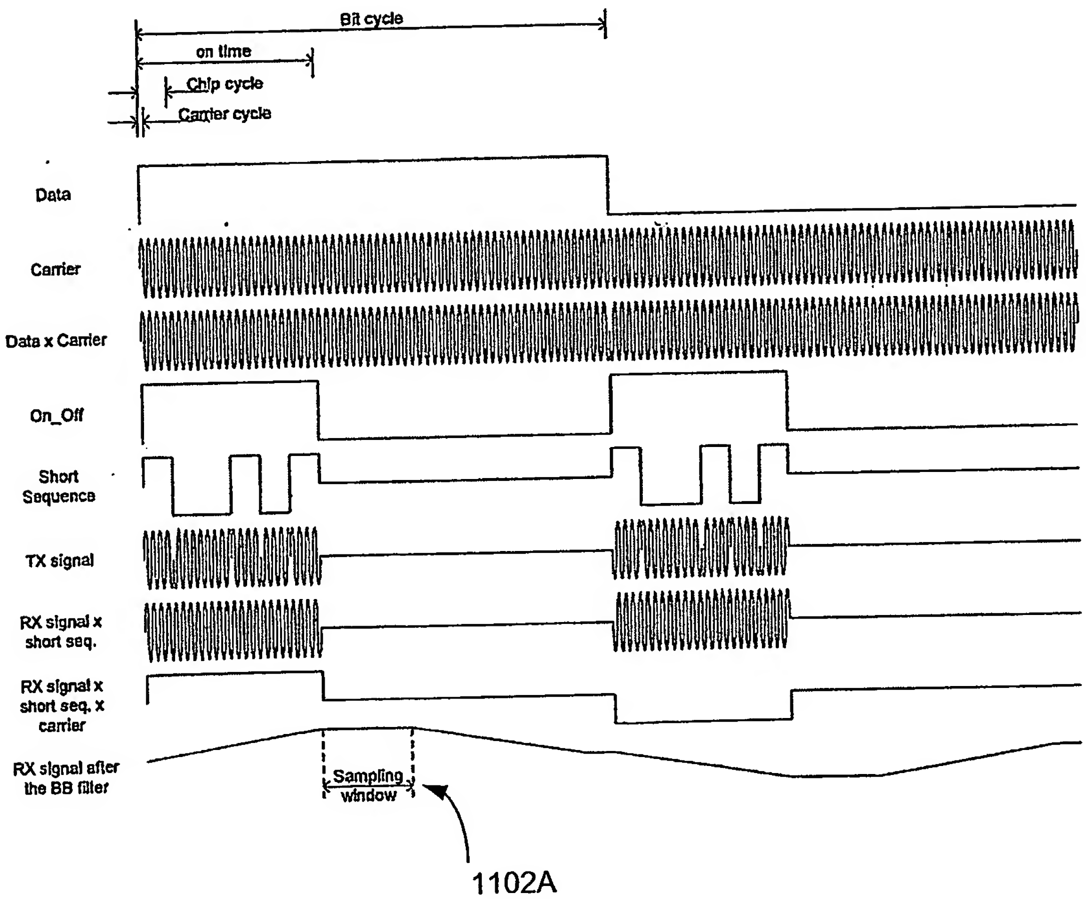

Bit cycle
on time
Chip cycle
Carrier cycle
Data
Carrier
Data x Carrier
On_Off
Short Sequence
TX signal
RX signal x short seq.
RX signal x short seq. x carrier
RX signal after the BB filter
Sampling window
1102A

Fig. 12

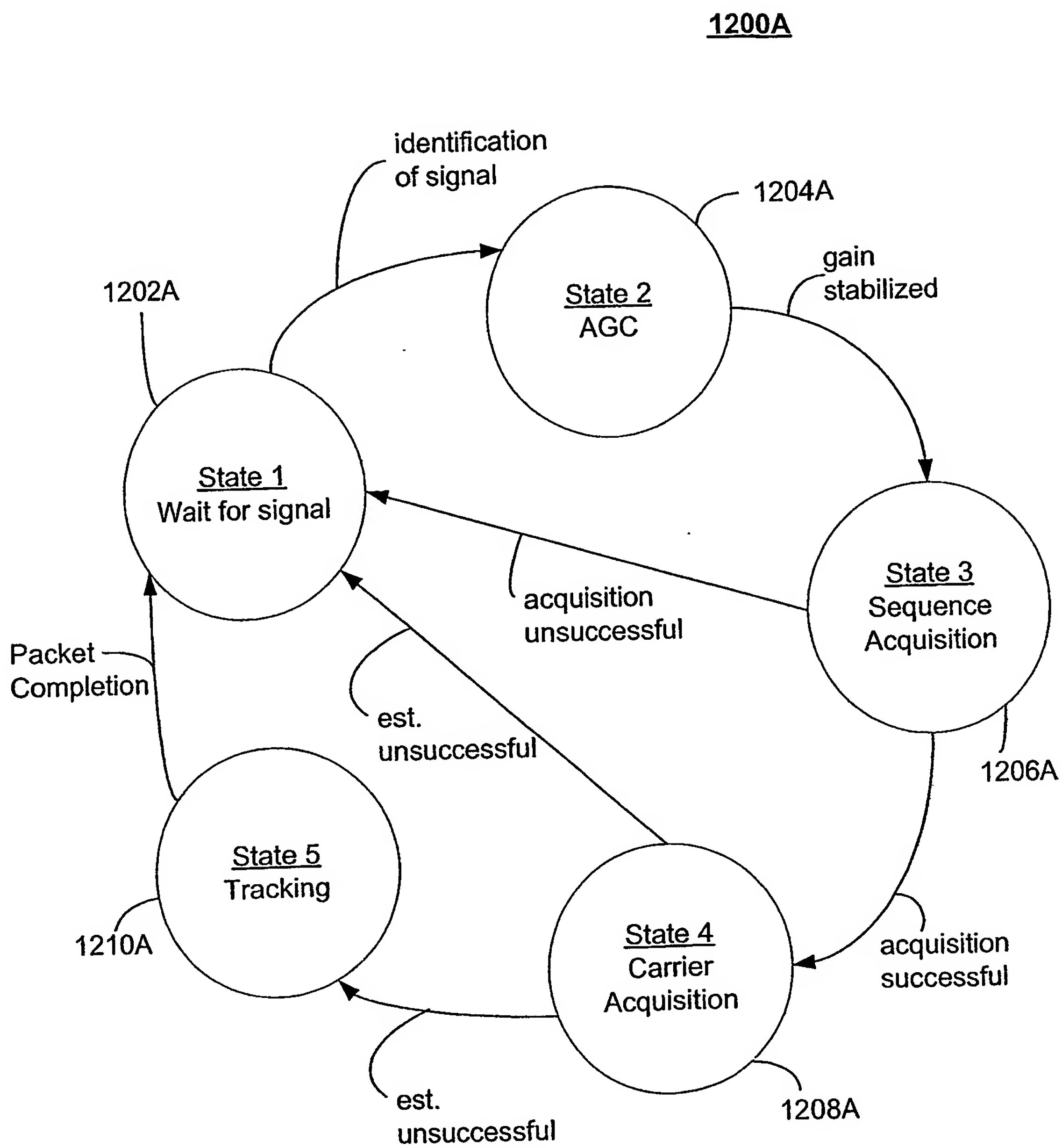

1200A
identification of signal
1204A
State 2
AGC
gain stabilized
1202A
State 1
Wait for signal
State 3
Sequence Acquisition
acquisition unsuccessful
Packet Completion
est. unsuccessful
1206A
State 5
Tracking
State 4
Carrier Acquisition
acquisition successful
1210A
est. unsuccessful
1208A

Fig. 13

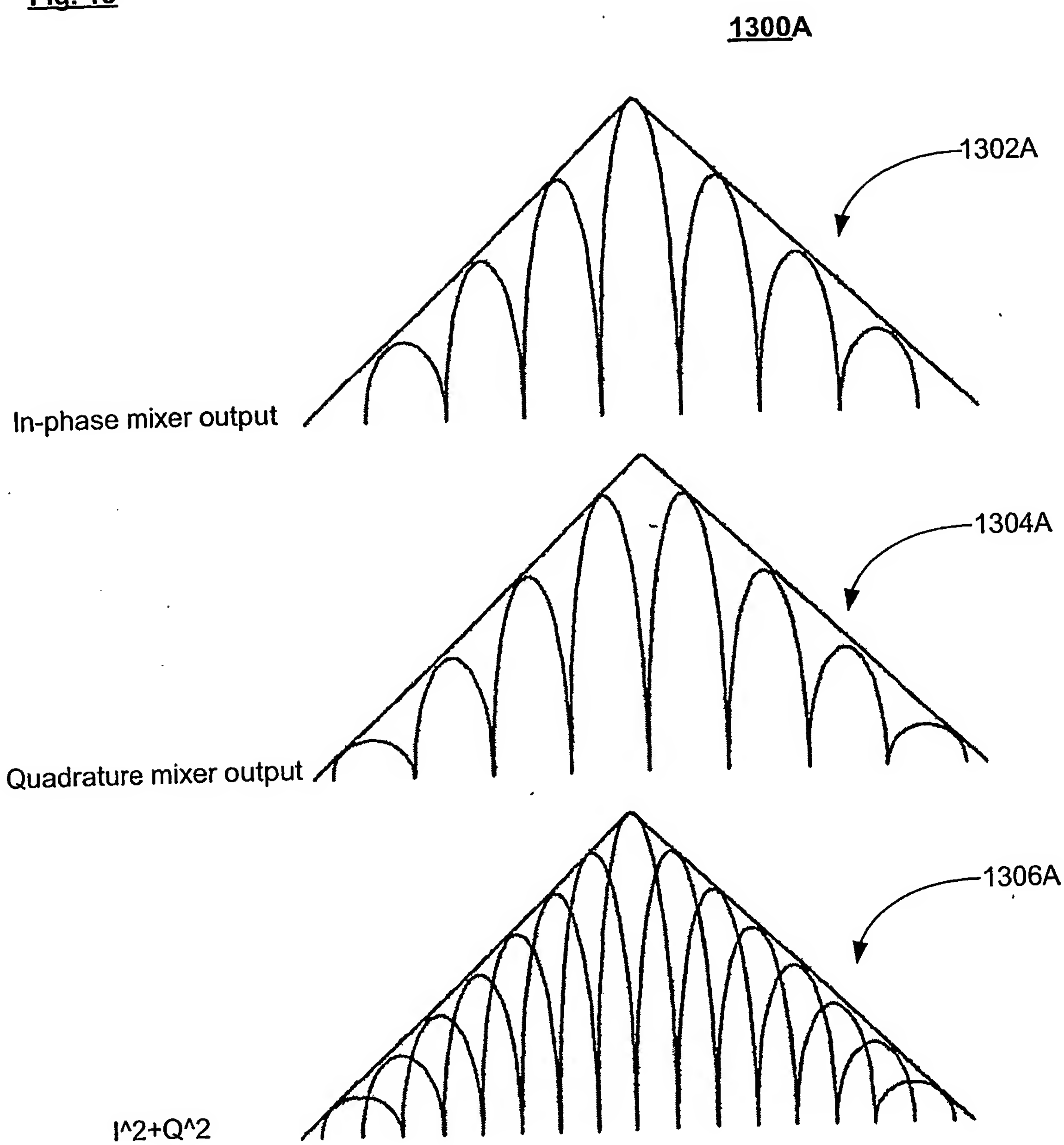

1300A
1302A
In-phase mixer output
1304A
Quadrature mixer output
1306A
I^2+Q^2

Fig. 14

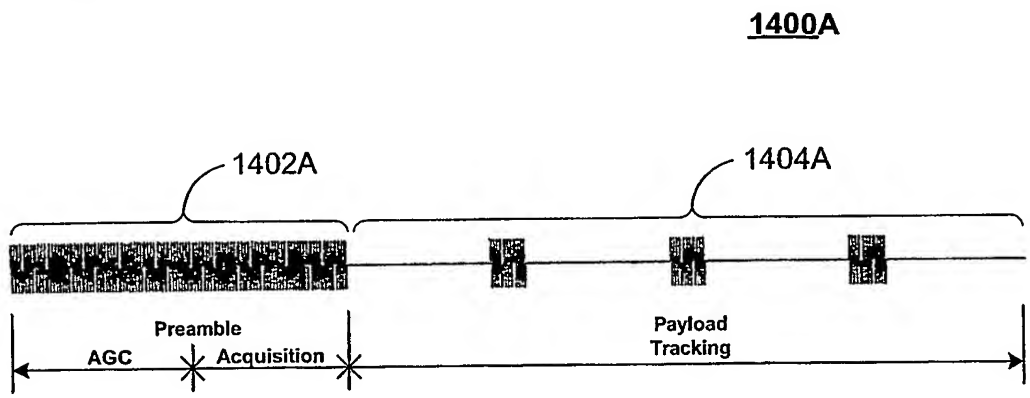

1400A
1402A
1404A
Preamble
AGC
Acquisition
Payload
Tracking

Fig. 15

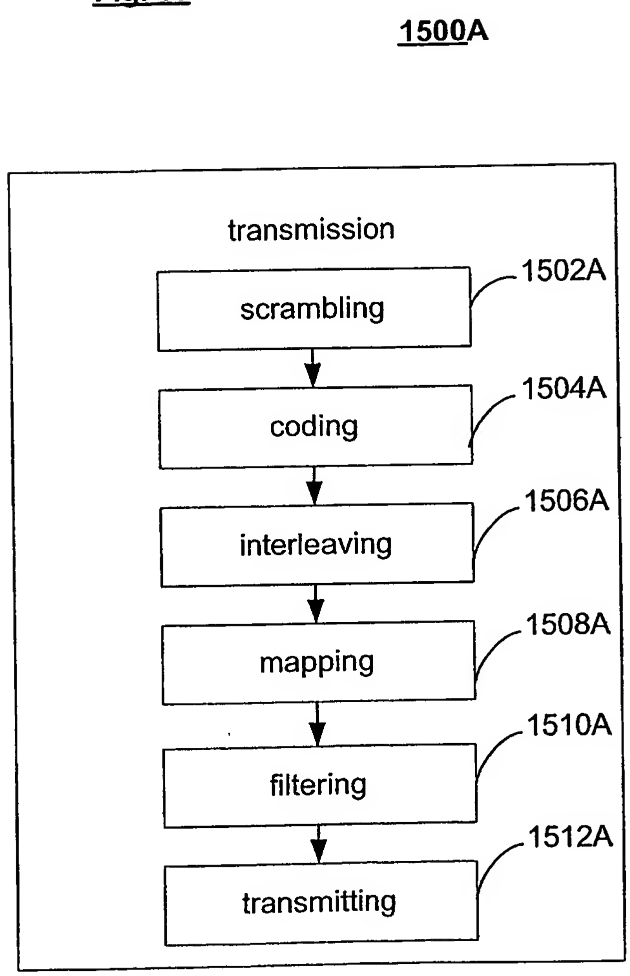

1500A
transmission
scrambling
1502A
coding
1504A
interleaving
1506A
mapping
1508A
filtering
1510A
transmitting
1512A

Fig. 16

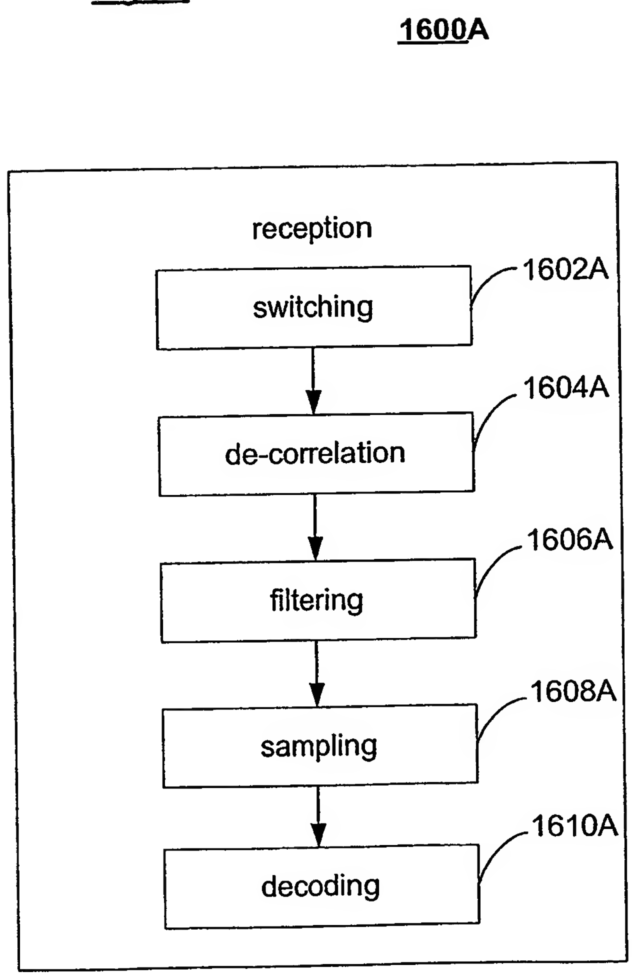

1600A
reception
switching
1602A
de-correlation
1604A
filtering
1606A
sampling
1608A
decoding
1610A

Fig. 17

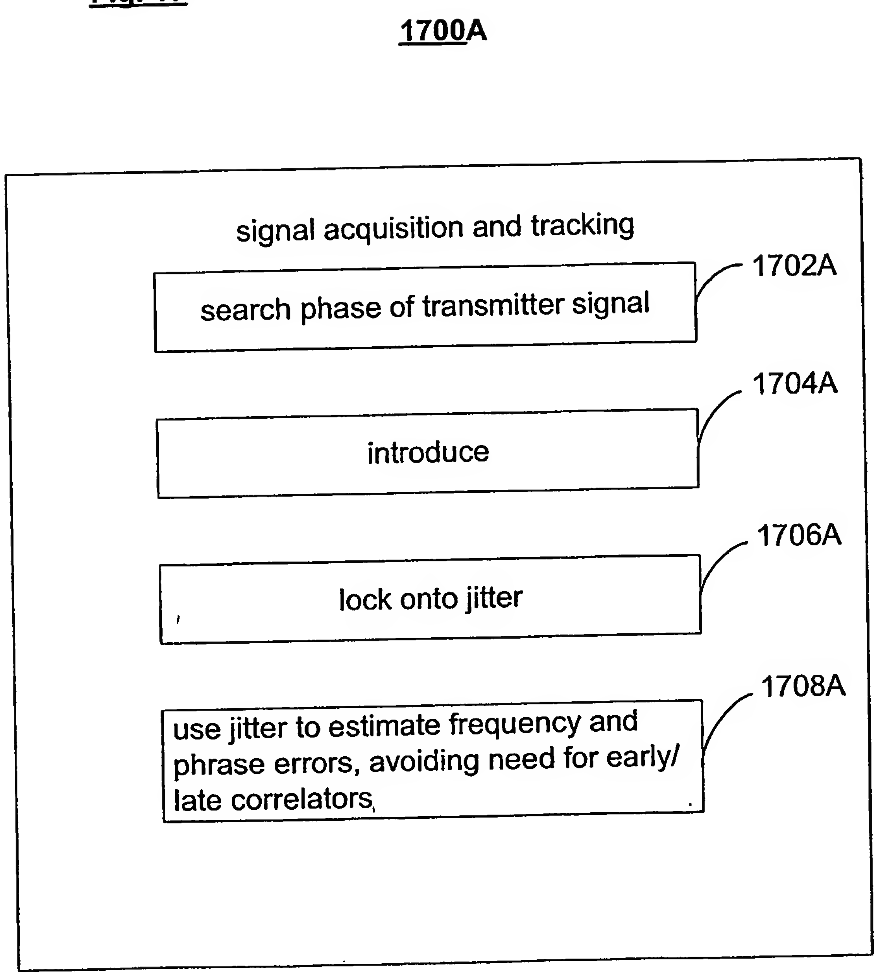

1700A
signal acquisition and tracking
search phase of transmitter signal
1702A
introduce
1704A
lock onto jitter
1706A
use jitter to estimate frequency and phrase errors, avoiding need for early/late correlators
1708A

Fig. 17A

1750A

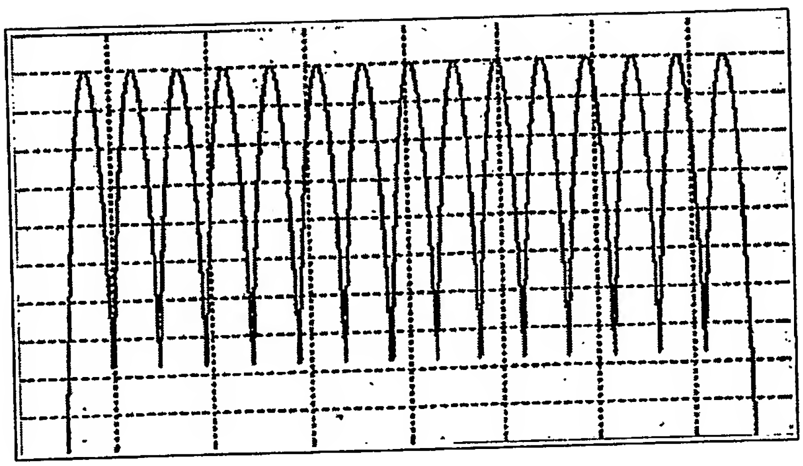
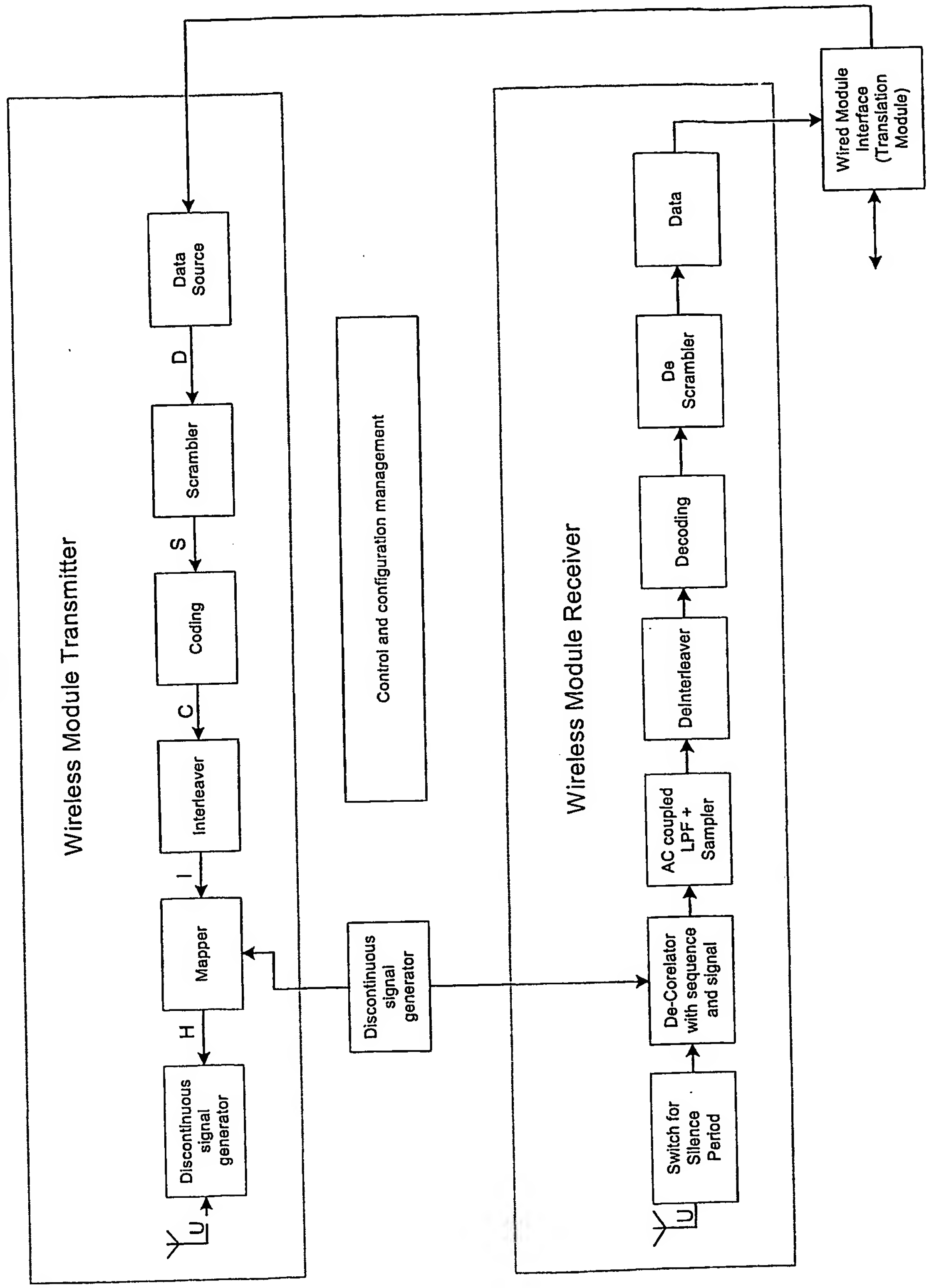


Fig. 18

1800A



Wireless Module Transmitter
Data Source
D
Scrambler
S
Coding
C
Interleaver
I
Mapper
H
Discontinuous signal generator
U
Control and configuration management
Discontinuous signal generator
Wireless Module Receiver
Switch for Silence Period
U
De-Corelator with sequence and signal
AC coupled LPF + Sampler
DeInterleaver
Decoding
De Scrambler
Data
Wired Module Interface (Translation Module)

Fig. 19

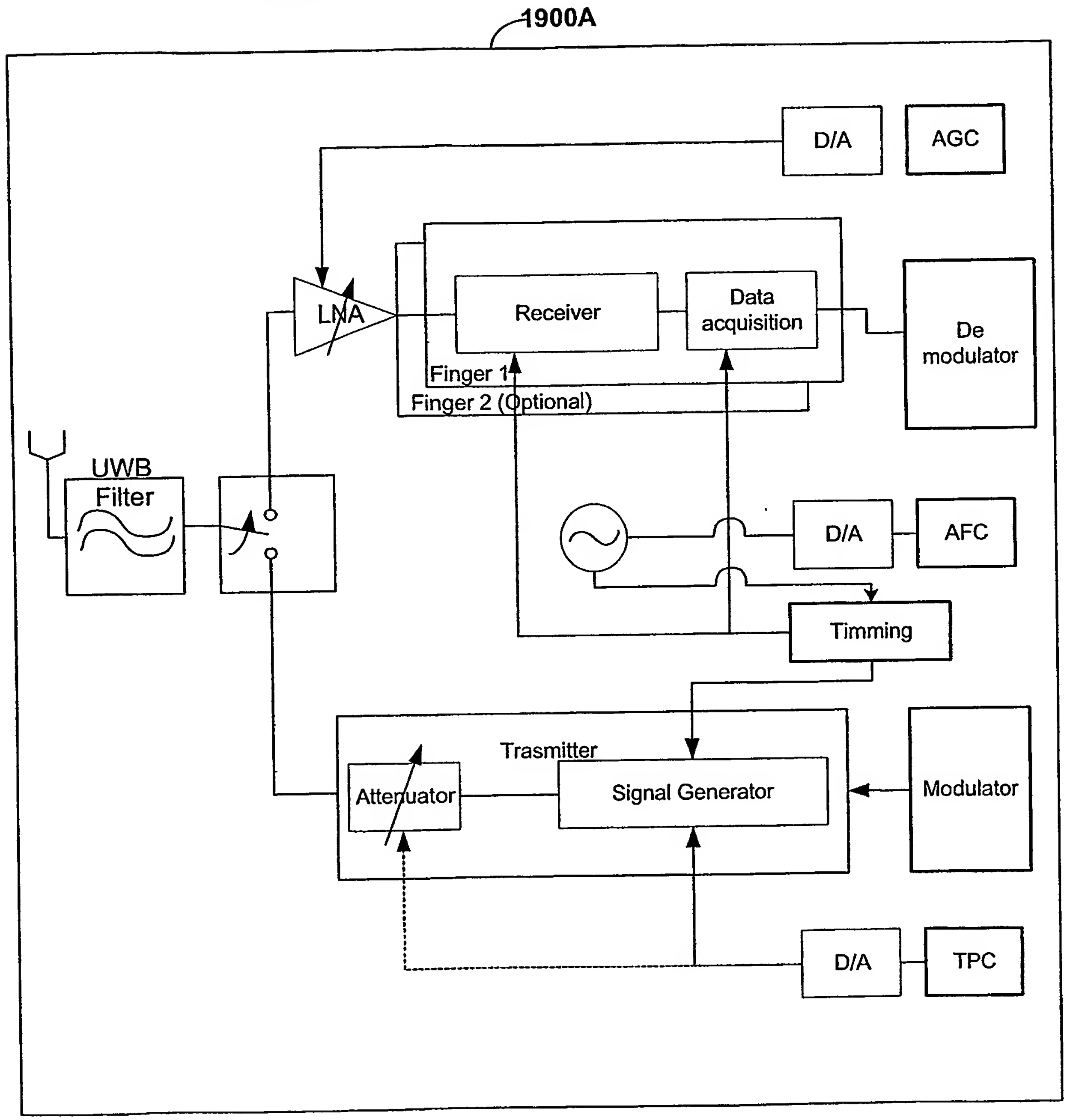

1900A
D/A
AGC
LNA
Receiver
Data acquisition
Finger 1
Finger 2 (Optional)
De modulator
UWB Filter
D/A
AFC
Timming
Trasmitter
Attenuator
Signal Generator
Modulator
D/A
TPC

Fig. 20

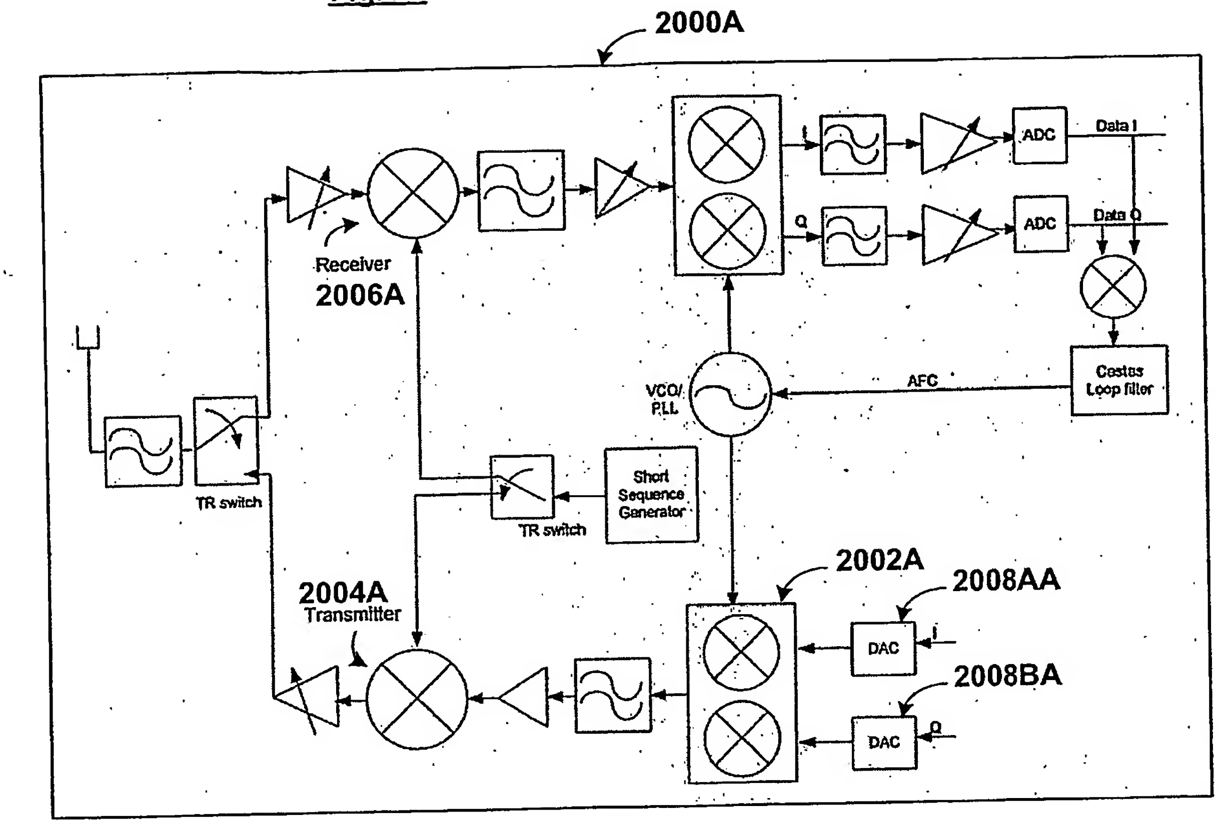

2000A
Receiver
2006A
Data I
Data Q
I
Q
ADC
ADC
VCO/
PLL
AFC
Costas
Loop filter
TR switch
Short
Sequence
Generator
TR switch
2002A
2008AA
2004A
Transmitter
DAC
I
2008BA
DAC
Q

Fig. 21

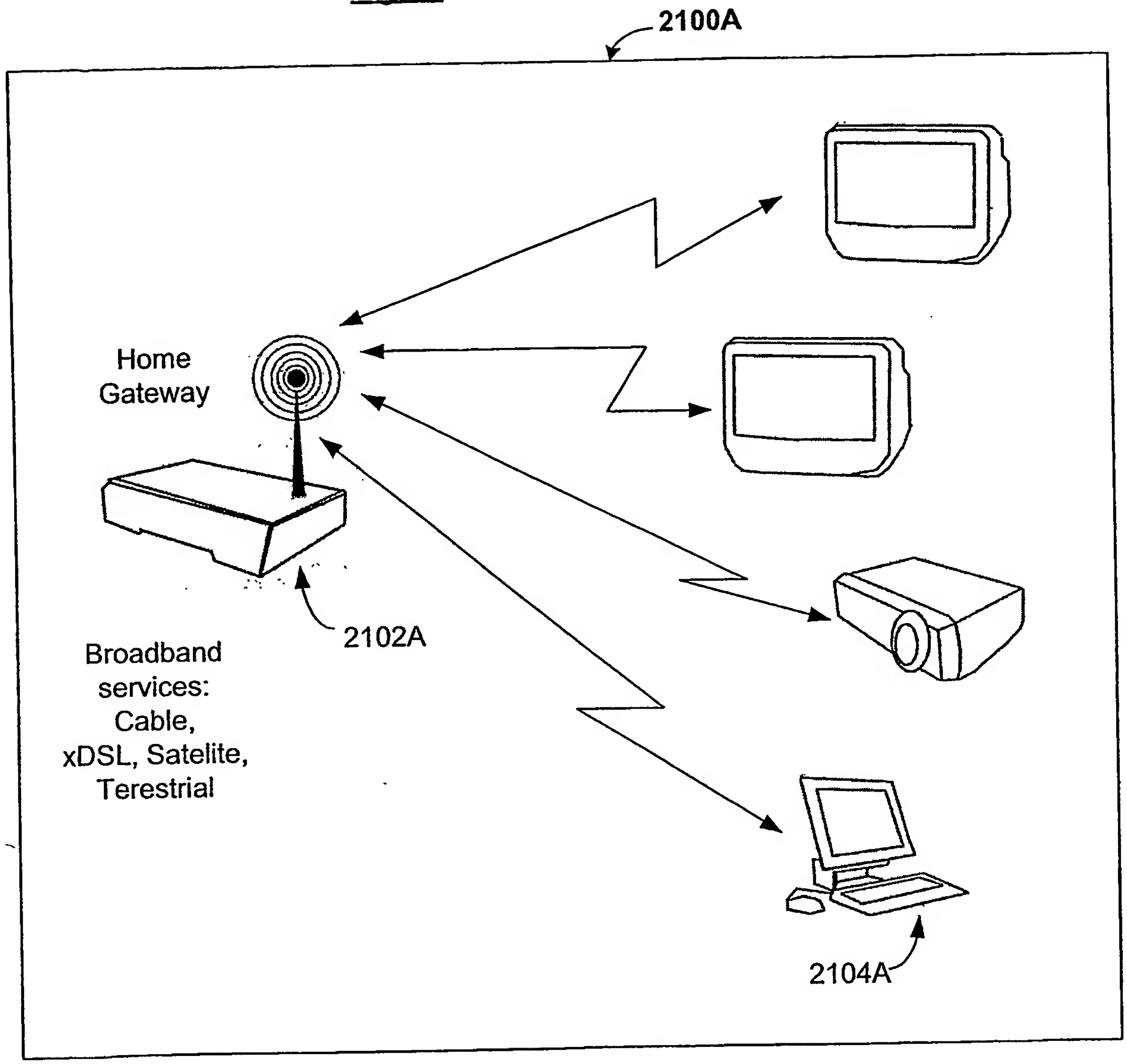

2100A
Home
Gateway
2102A
Broadband
services:
Cable,
xDSL, Satelite,
Terestrial
2104A

Fig. 22

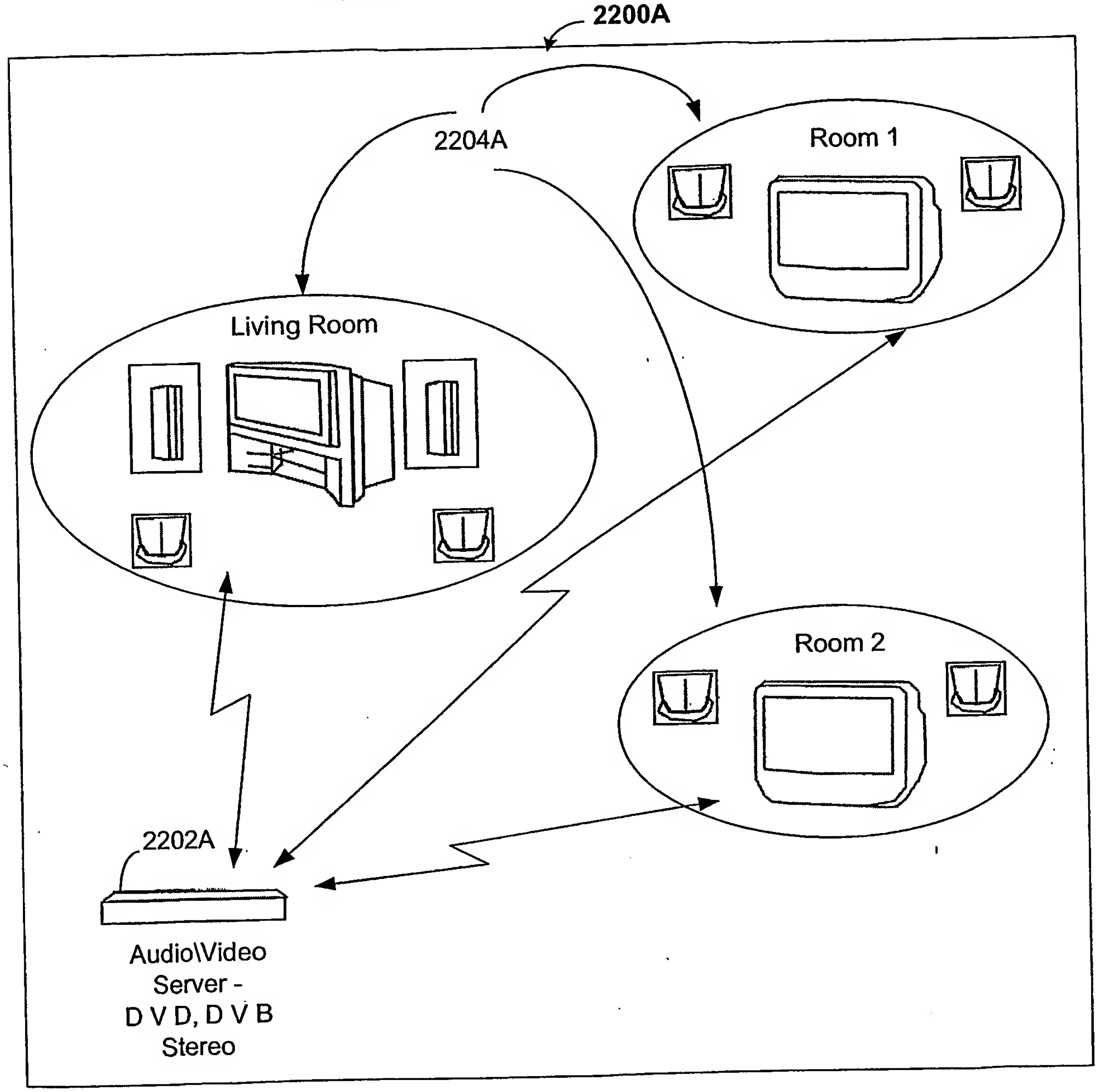

2200A
2204A
Room 1
Living Room
Room 2
2202A
Audio\Video
Server -
D V D, D V B
Stereo

Fig. 23

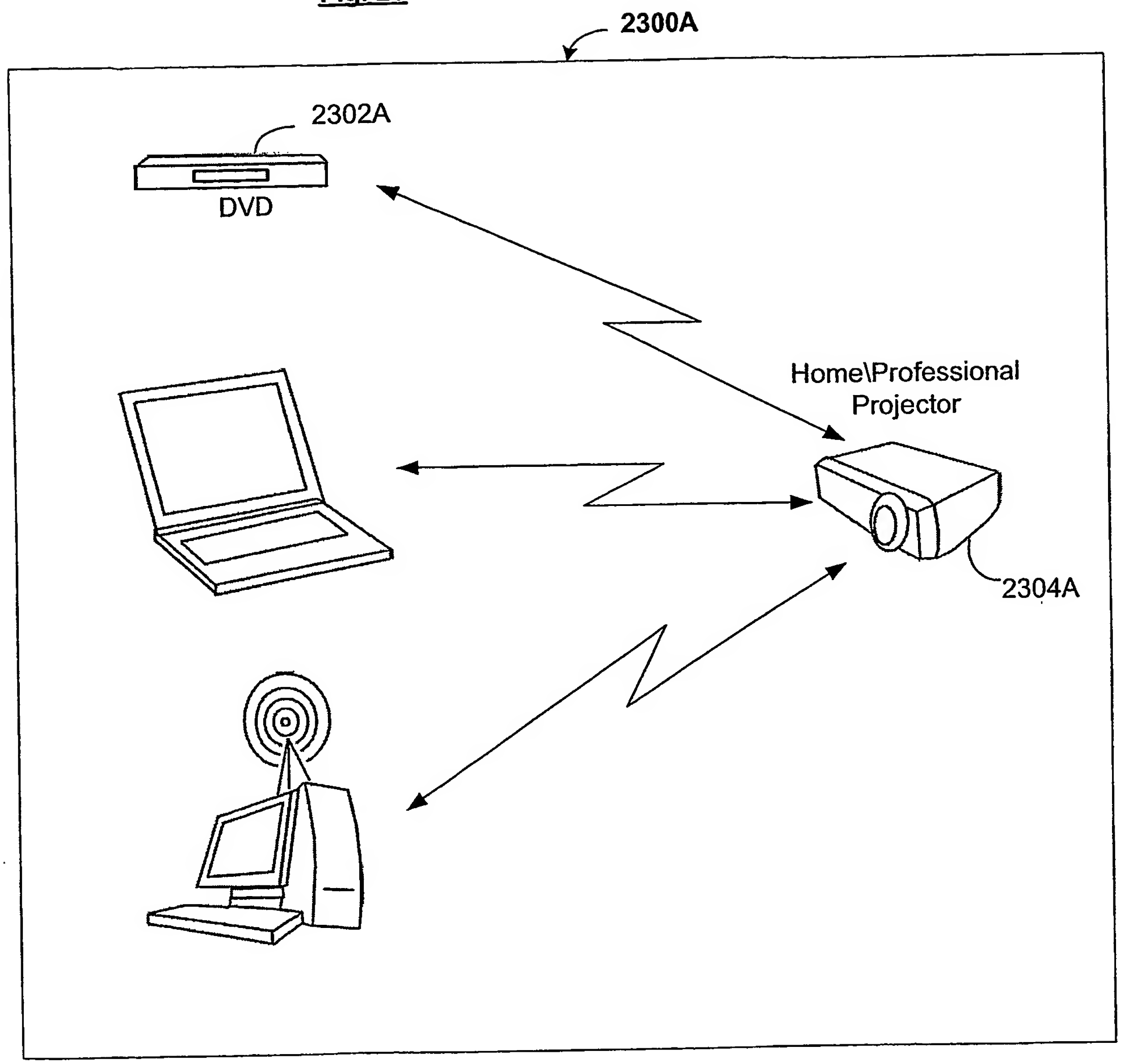


Fig. 24

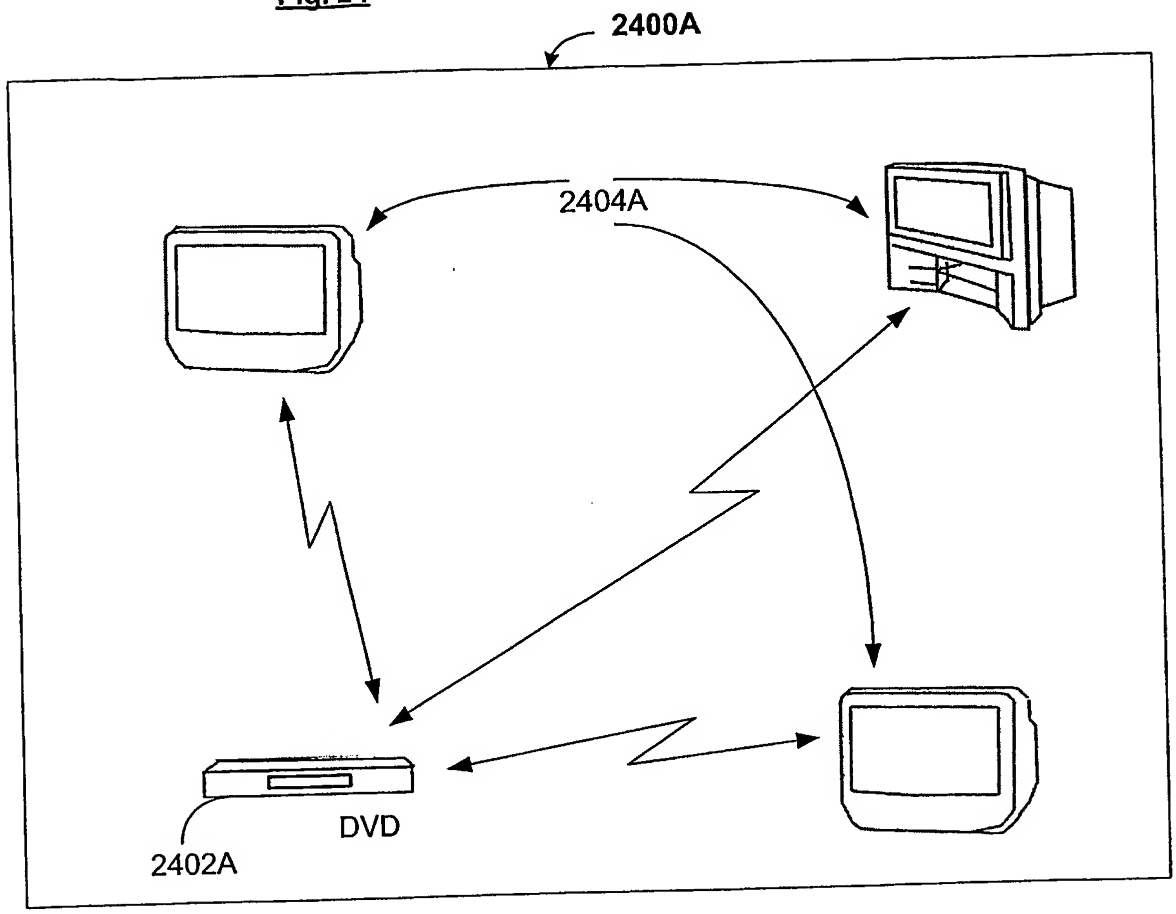


Fig. 25

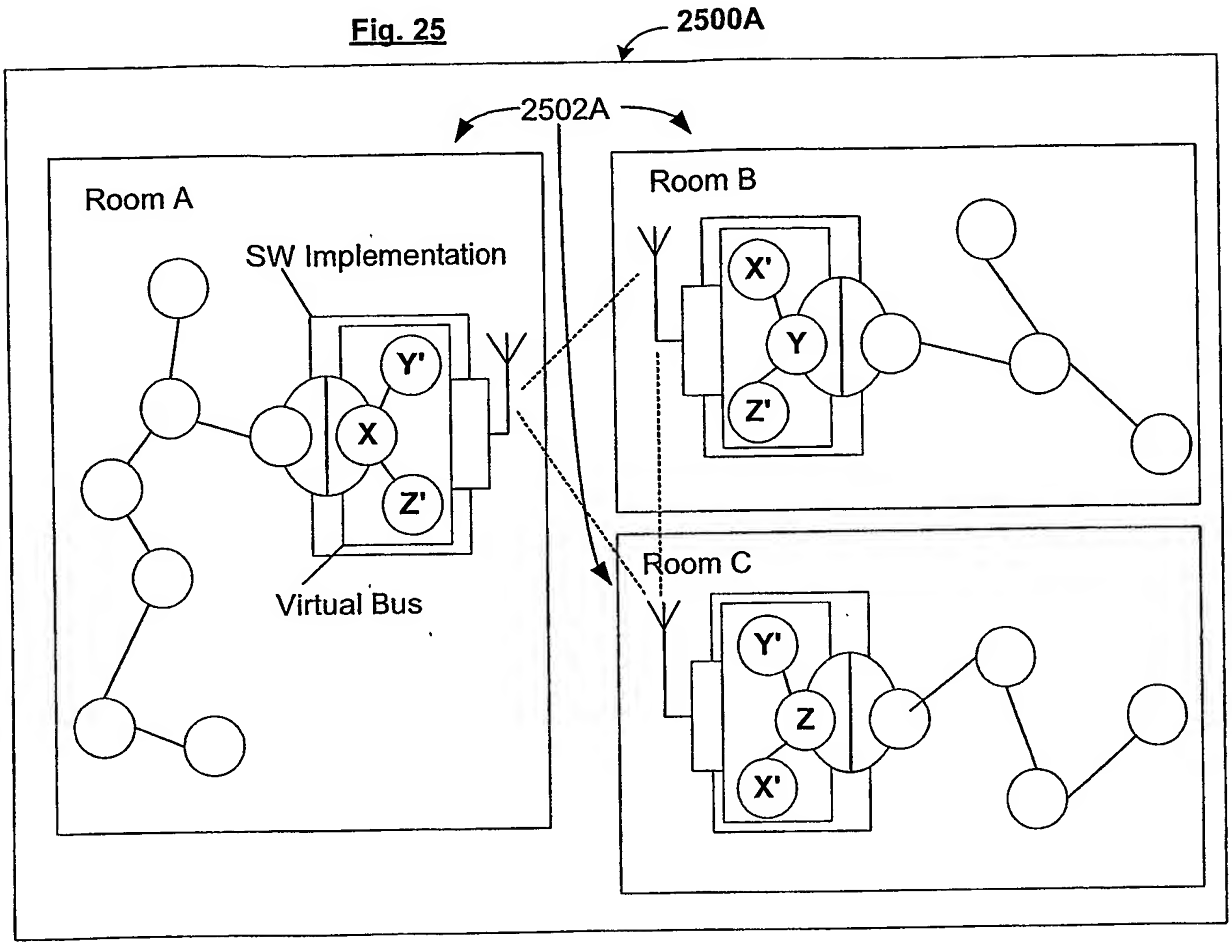
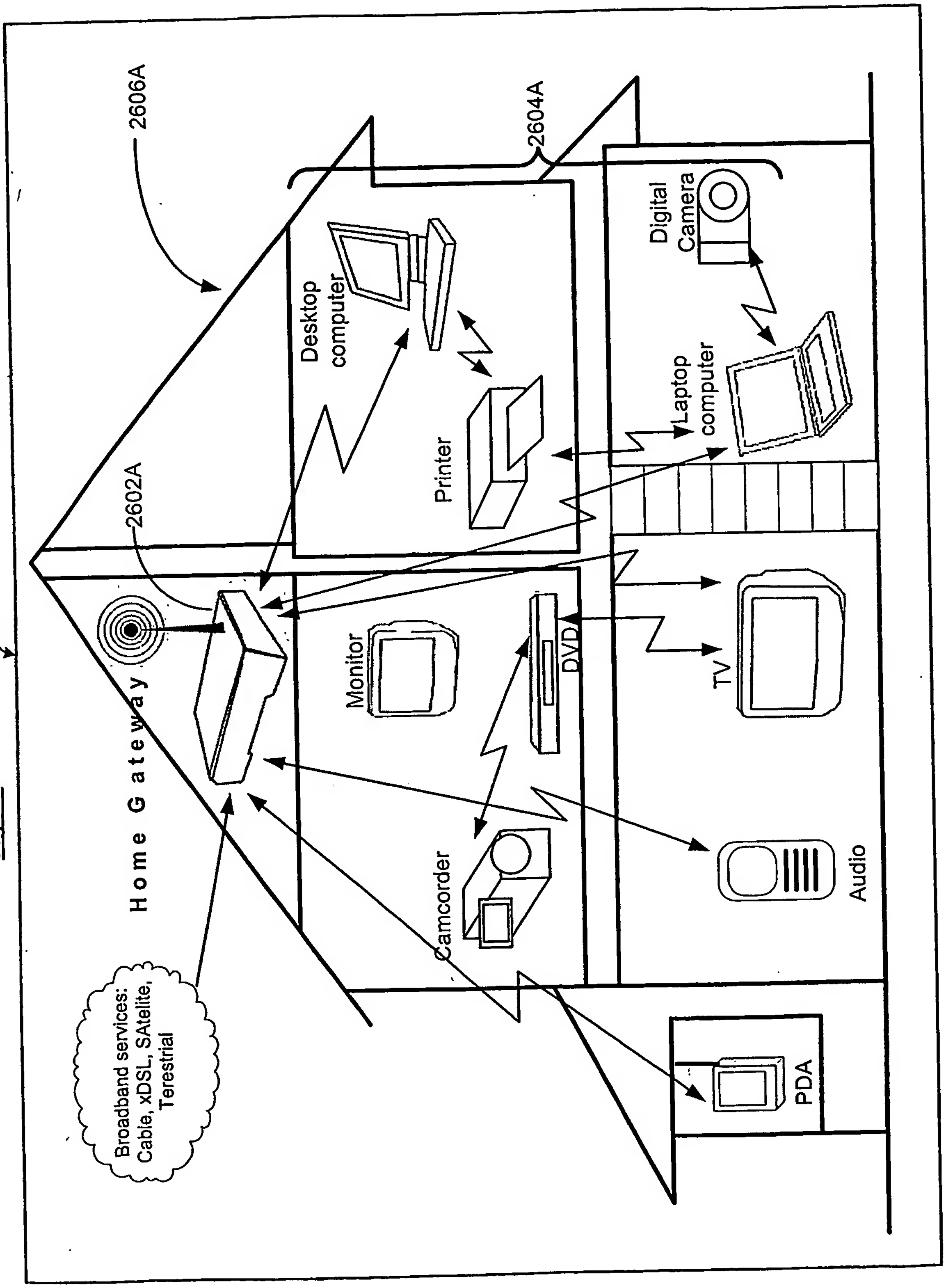

2500A
2502A
Room A
SW Implementation
Y'
X
Z'
Virtual Bus
Room B
X'
Y
Z'
Room C
Y'
Z
X'

Fig. 26


2600A
2606A
2602A
2604A
Home Gateway
Broadband services:
Cable, xDSL, SAtelite,
Terestrial
Desktop
computer
Printer
Digital
Camera
Laptop
computer
Monitor
DVD
TV
Camcorder
Audio
PDA

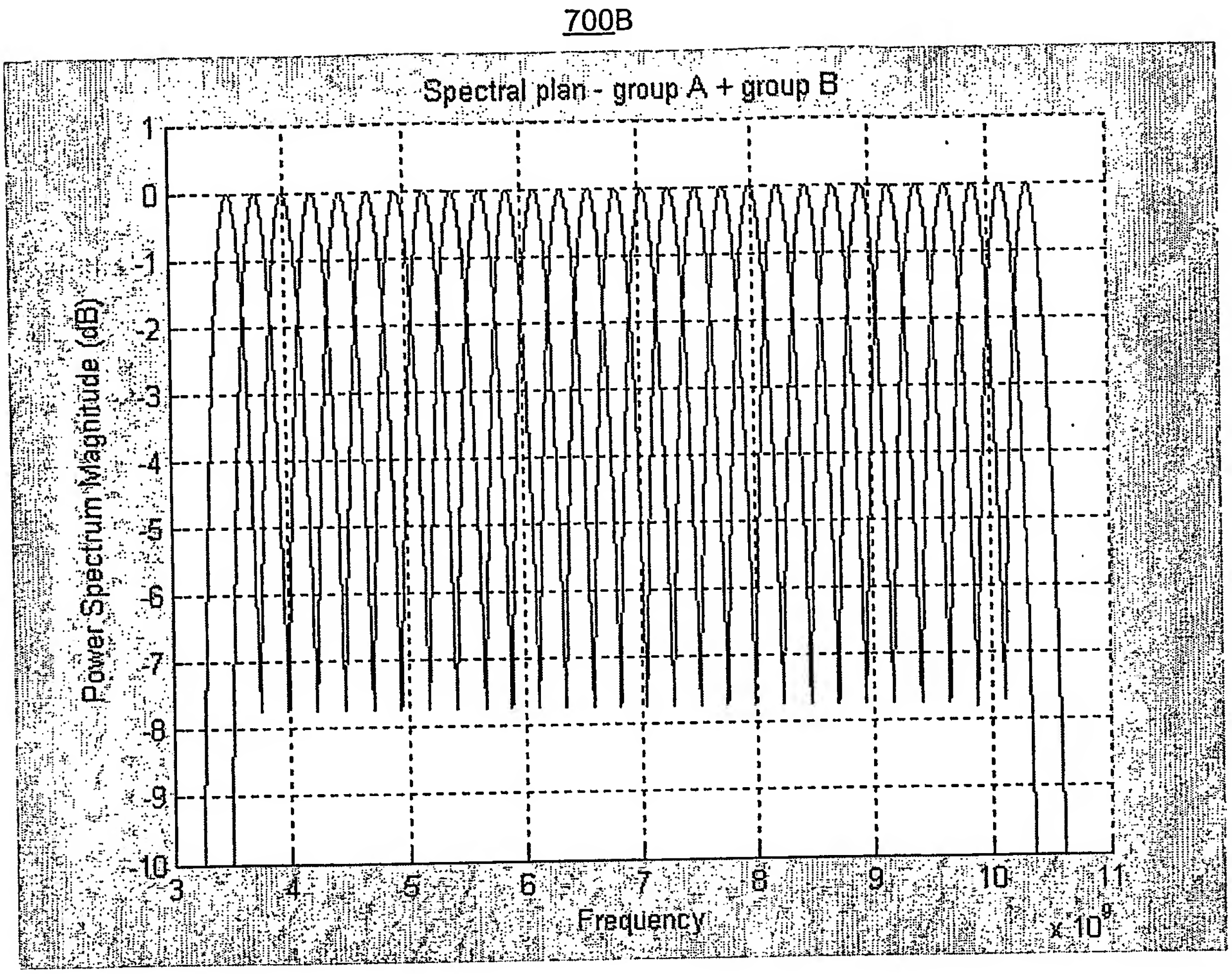

700B
Spectral plan - group A + group B
Power Spectrum Magnitude (dB)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
3
4
5
6
7
8
9
10
11
Frequency
x 10^9

Figure 27

800B

S1	1	2	3	4	5	6	7
S2	1	3	5	7	2	4	6
S3	1	4	7	3	6	2	5
S4	1	5	2	6	3	7	4
S5	1	6	4	2	7	5	3
S6	1	7	6	5	4	3	2

Figure 28

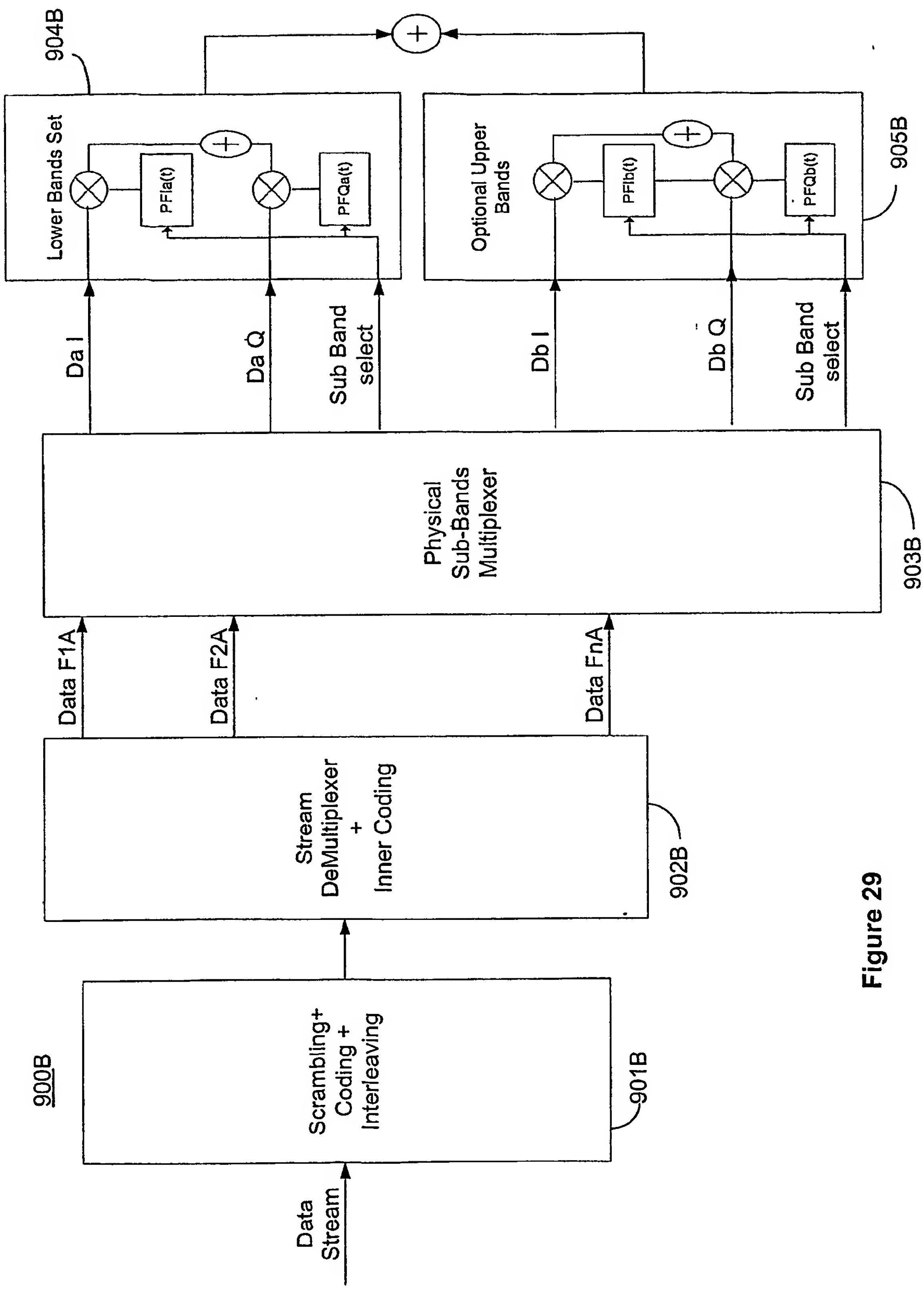

904B
Lower Bands Set
PFIa(t)
PFQa(t)
Optional Upper Bands
PFIb(t)
PFQb(t)
905B
Da I
Da Q
Sub Band select
Db I
Db Q
Sub Band select
Physical Sub-Bands Multiplexer
903B
Data F1A
Data F2A
Data FnA
Stream DeMultiplexer + Inner Coding
902B
900B
Scrambling+ Coding + Interleaving
901B
Data Stream

Figure 29

1000B

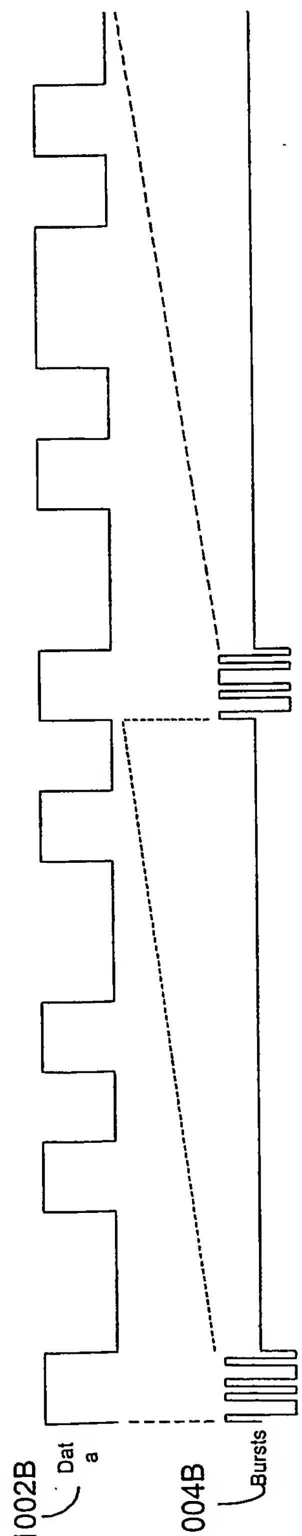


Figure 30

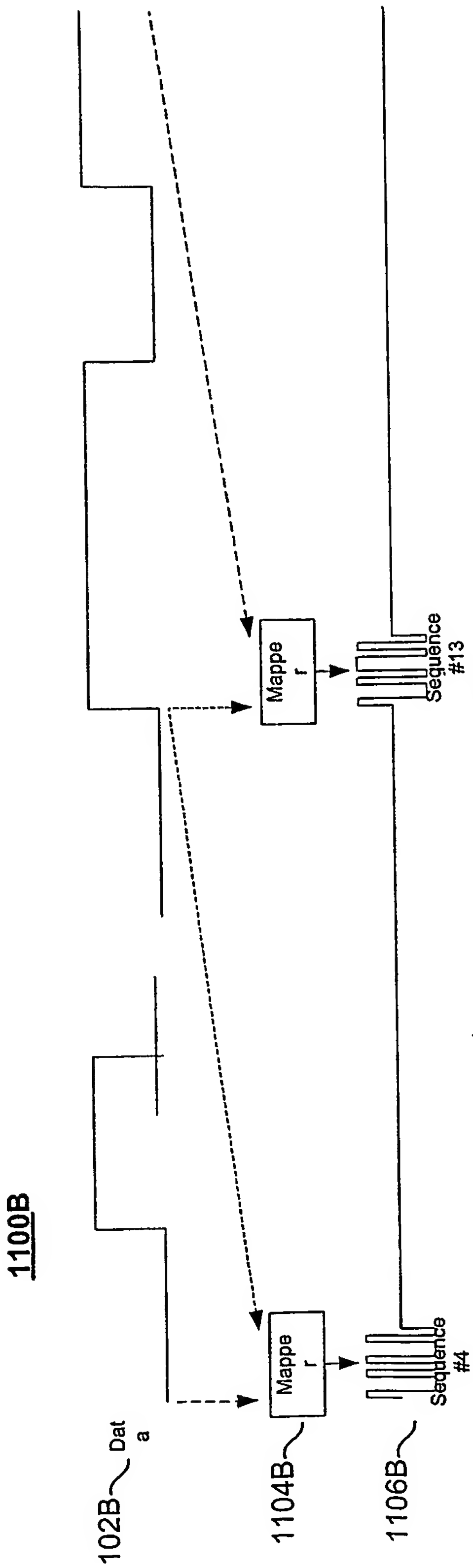

1100B
1102B
Dat
a
1104B
Mappe
r
1106B
Sequence
#4
Mappe
r
Sequence
#13

Figure 31

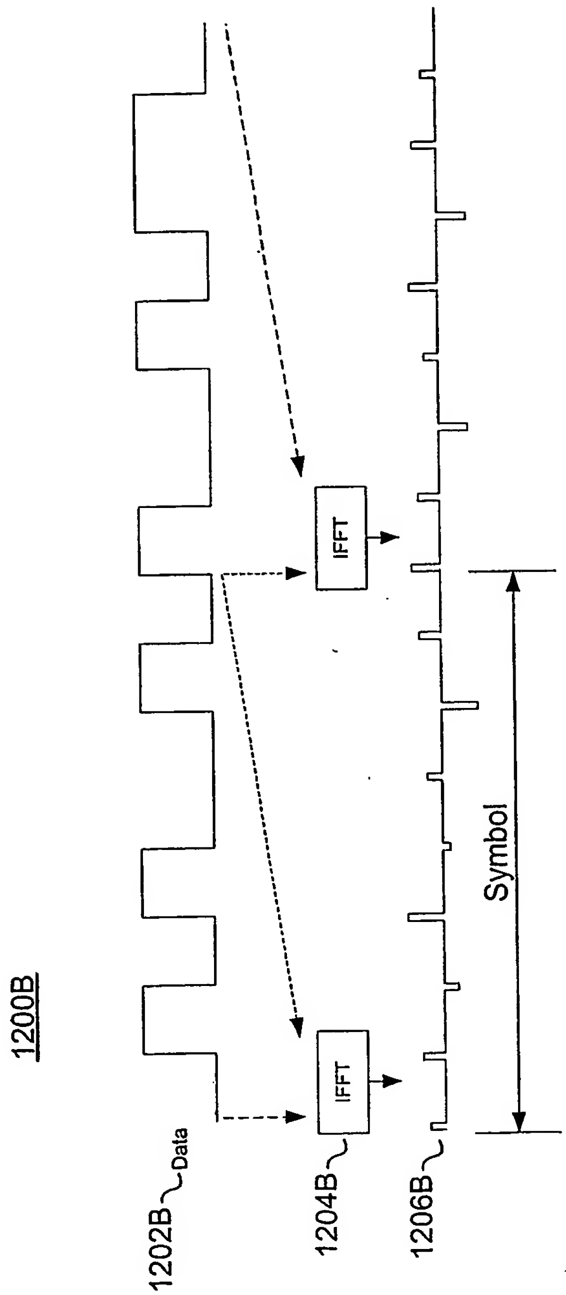


Figure 32

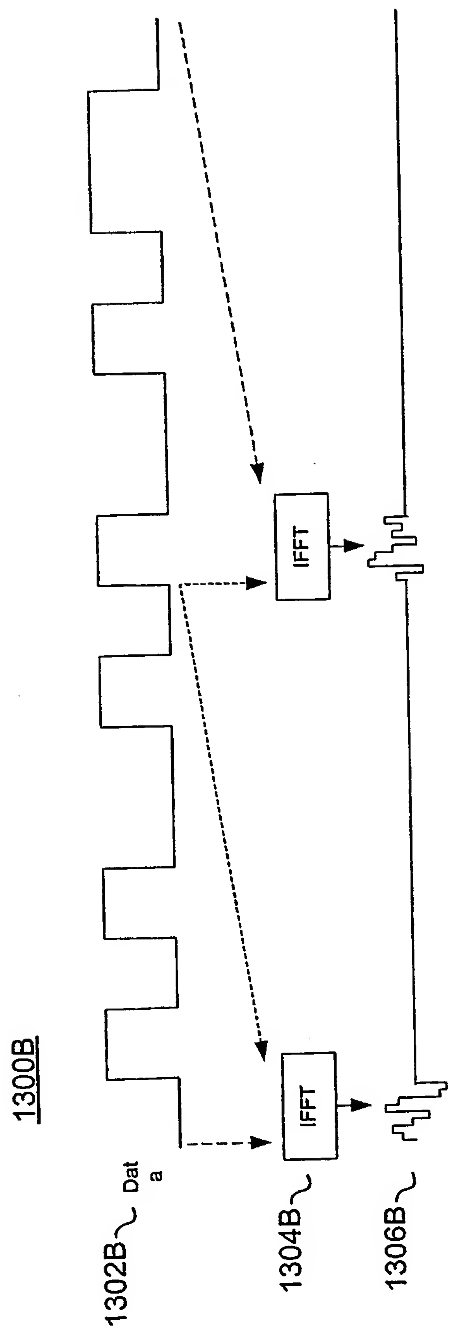


Figure 33

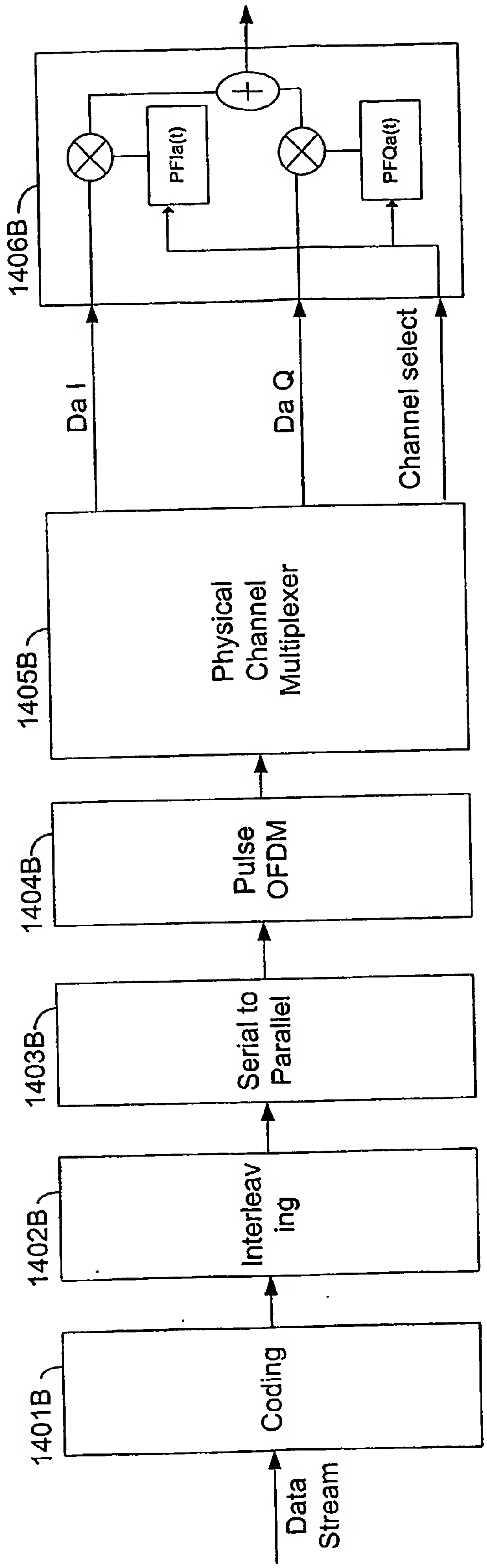

Data Stream
1401B
Coding
1402B
Interleaving
1403B
Serial to Parallel
1404B
Pulse OFDM
1405B
Physical Channel Multiplexer
Da I
Da Q
Channel select
1406B
PFIa(t)
PFQa(t)

Figure 34

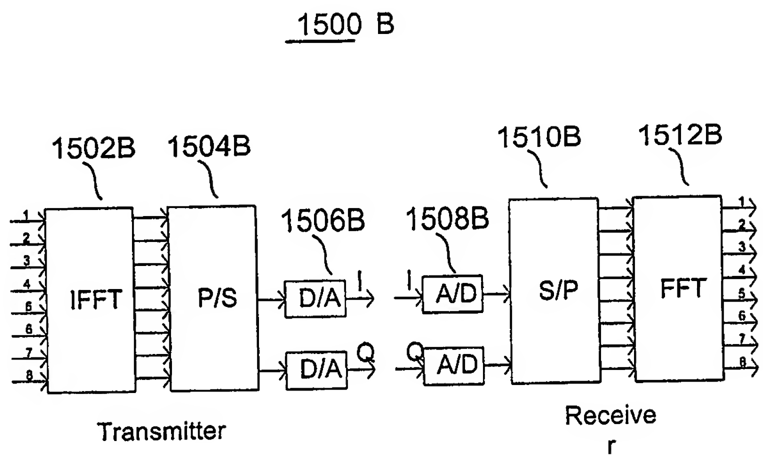

1500 B
1502B
1504B
1506B
1508B
1510B
1512B
IFFT
P/S
D/A
D/A
I
Q
A/D
A/D
S/P
FFT
1
2
3
4
5
6
7
8
Transmitter
Receive
r

Figure 35

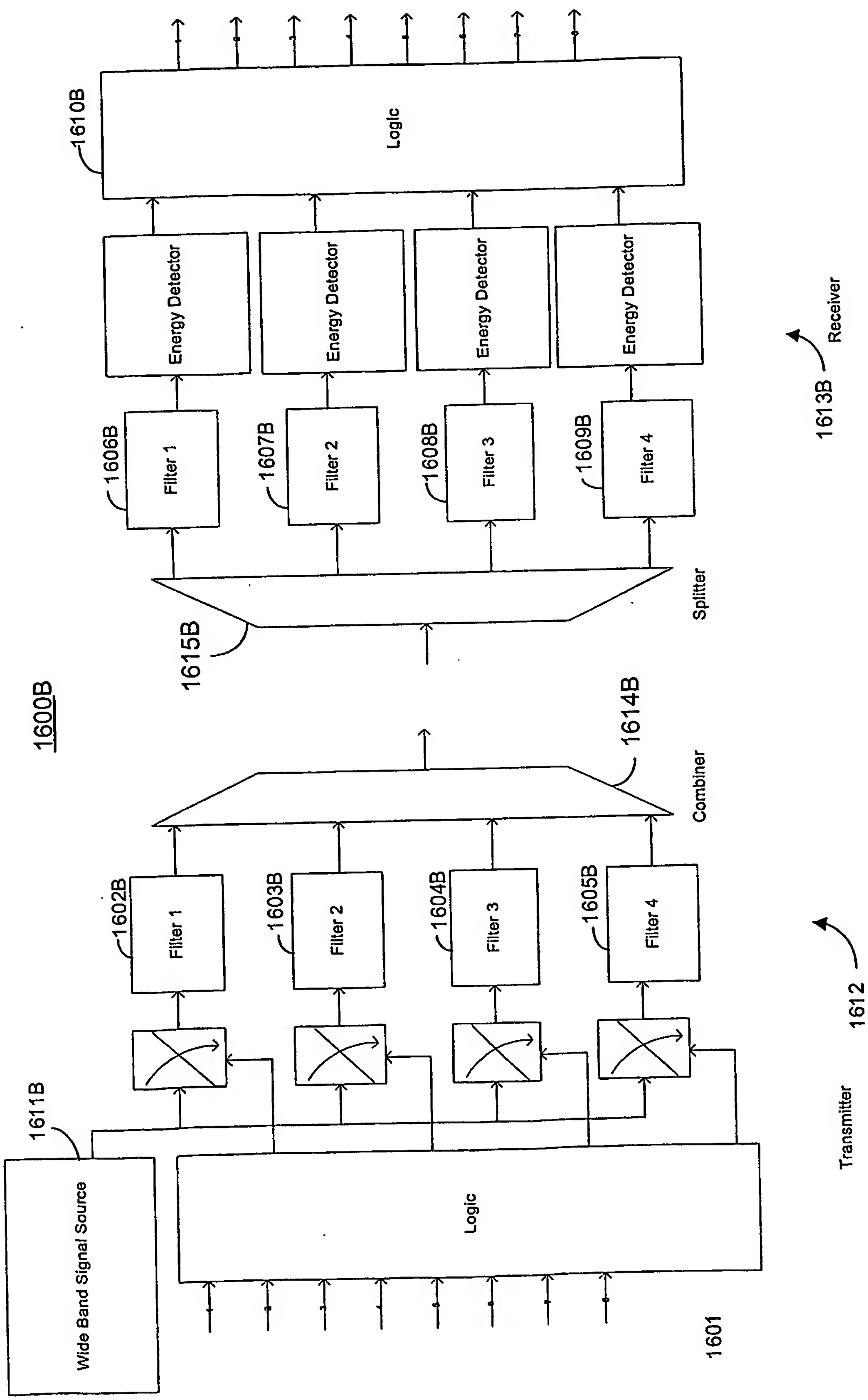

1600B
Wide Band Signal Source
1611B
Logic
1601
1602B
Filter 1
1603B
Filter 2
1604B
Filter 3
1605B
Filter 4
1612
Transmitter
Combiner
1614B
1615B
Splitter
1606B
Filter 1
1607B
Filter 2
1608B
Filter 3
1609B
Filter 4
Energy Detector
Energy Detector
Energy Detector
Energy Detector
1613B
Receiver
1610B
Logic

Figure 36

1700B

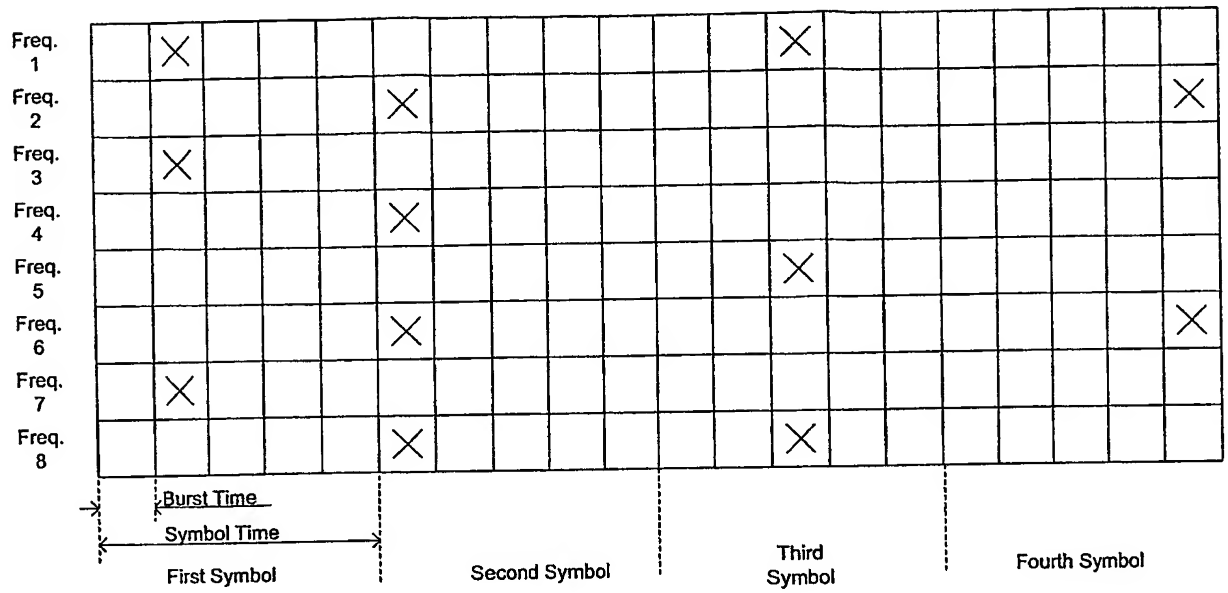


Figure 37

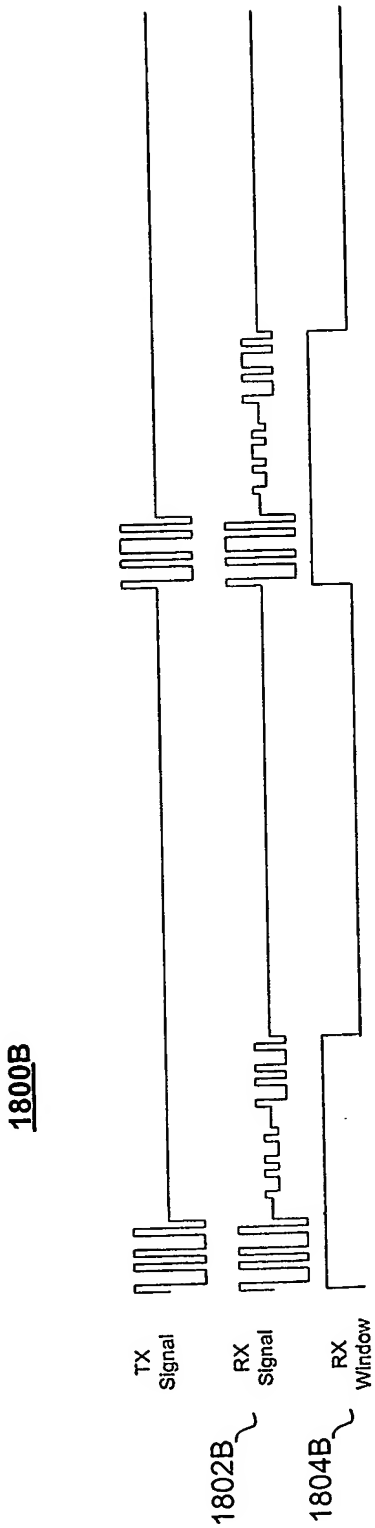


Figure 38

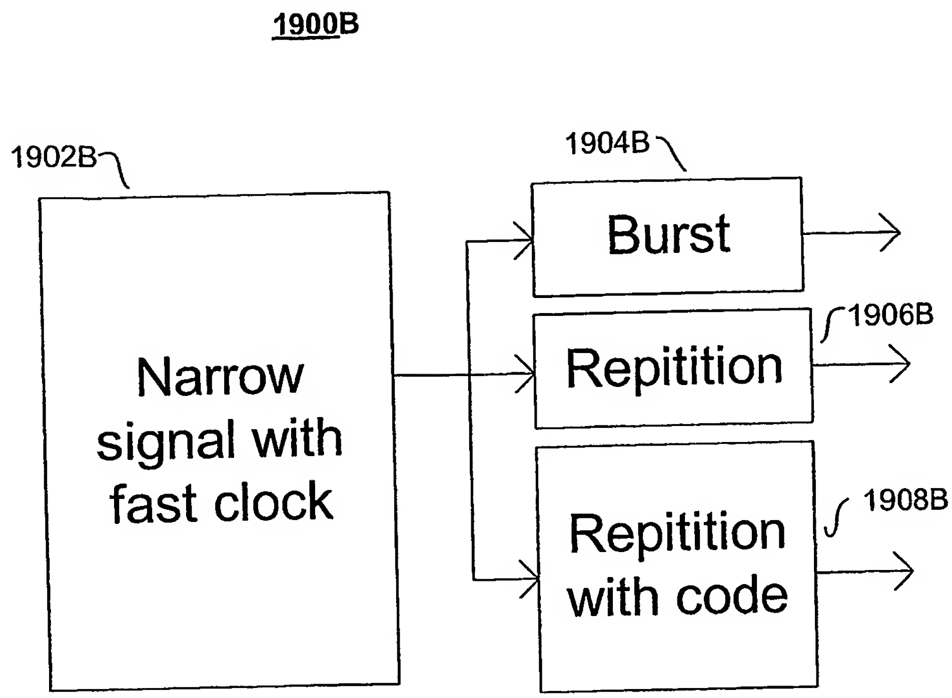

1900B
1902B
Narrow signal with fast clock
1904B
Burst
1906B
Repitition
1908B
Repitition with code

Figure 39

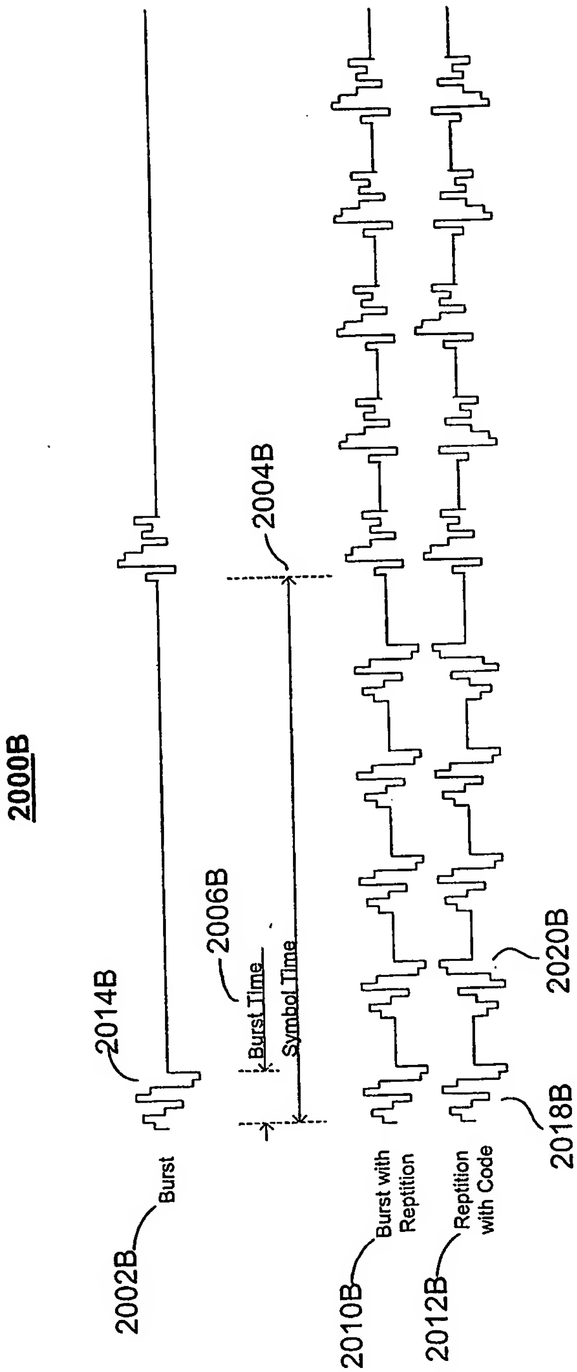

2000B
2002B
Burst
2014B
2006B
Burst Time
Symbol Time
2004B
2010B
Burst with Reptition
2012B
Reptition with Code
2018B
2020B

Figure 40

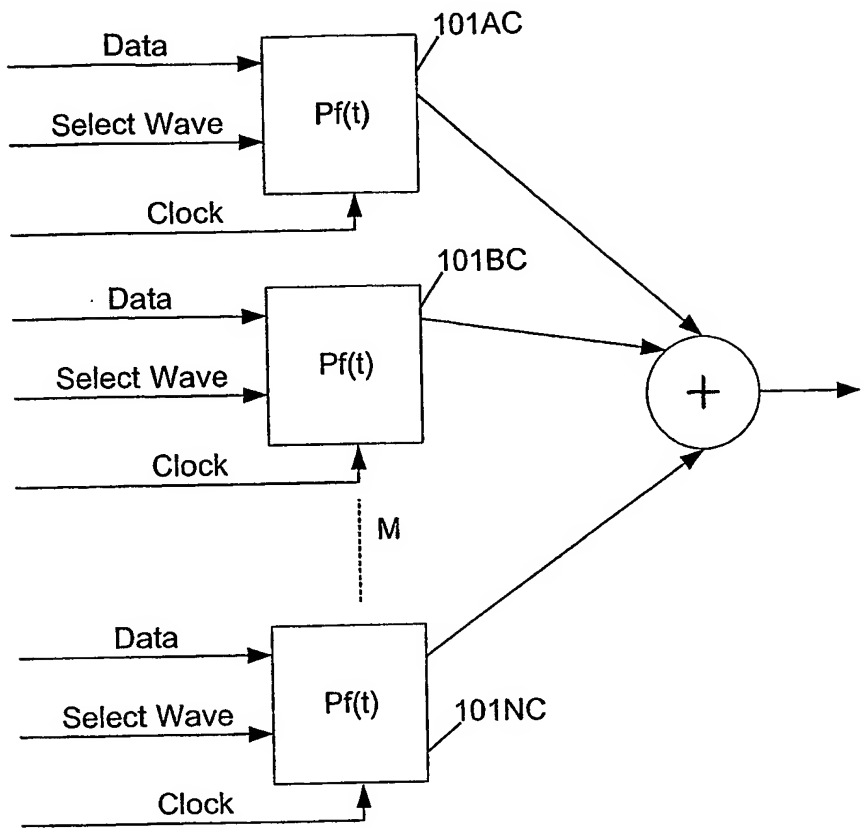
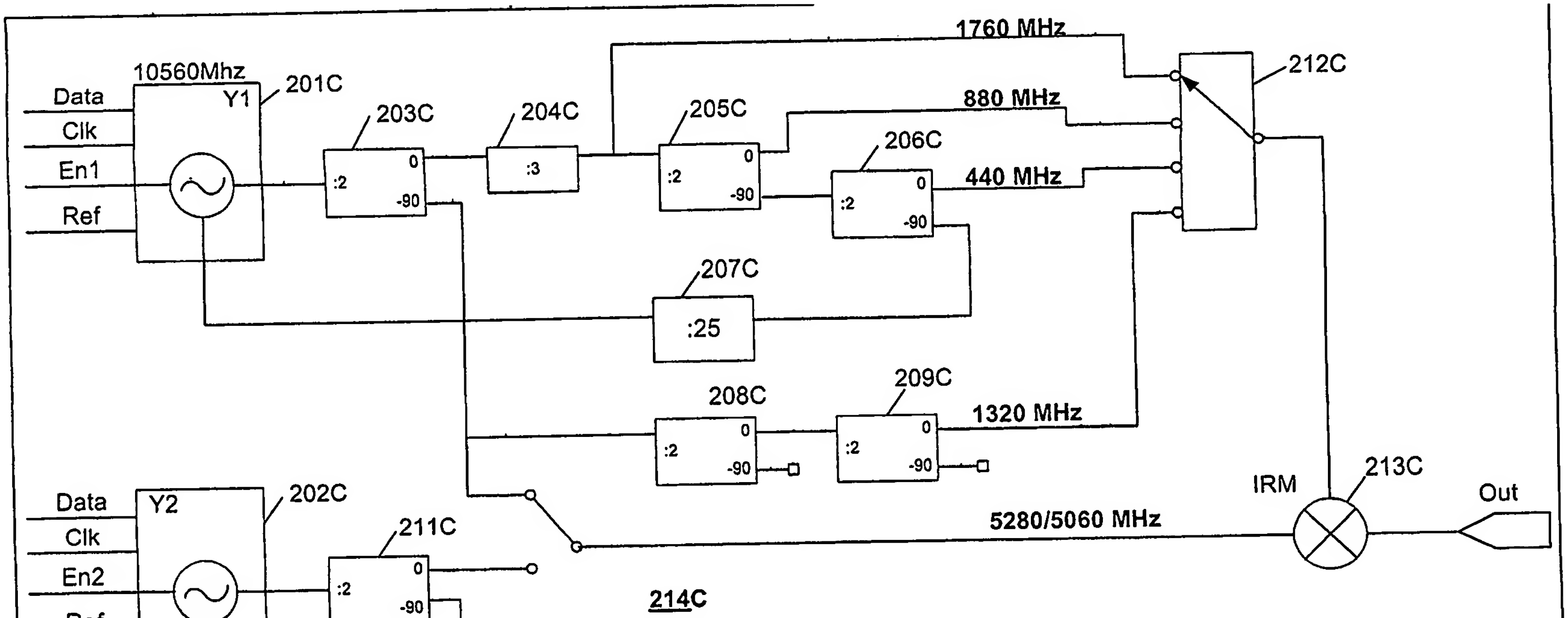

101AC
Data
Select Wave
Pf(t)
Clock
101BC
Data
Select Wave
Pf(t)
Clock
+
M
Data
Select Wave
Pf(t)
101NC
Clock

Figure 41



214C

Channel	LO[MHz]		IF[MHz]	RF Out[MHz]	
	Group A	Group B		Group A	Group B
1	5280	5060	1320	3520	3740
2	5280	5060	880	3960	4180
3	5280	5060	440	4400	4620
4	5280	5060	0	4840	5060
5	5280	5060	440	5280	5500
6	5280	5060	880	5720	5940
7	5280	5060	1320	6160	6380
8	5280	5060	1760	6600	6820

Figure 42

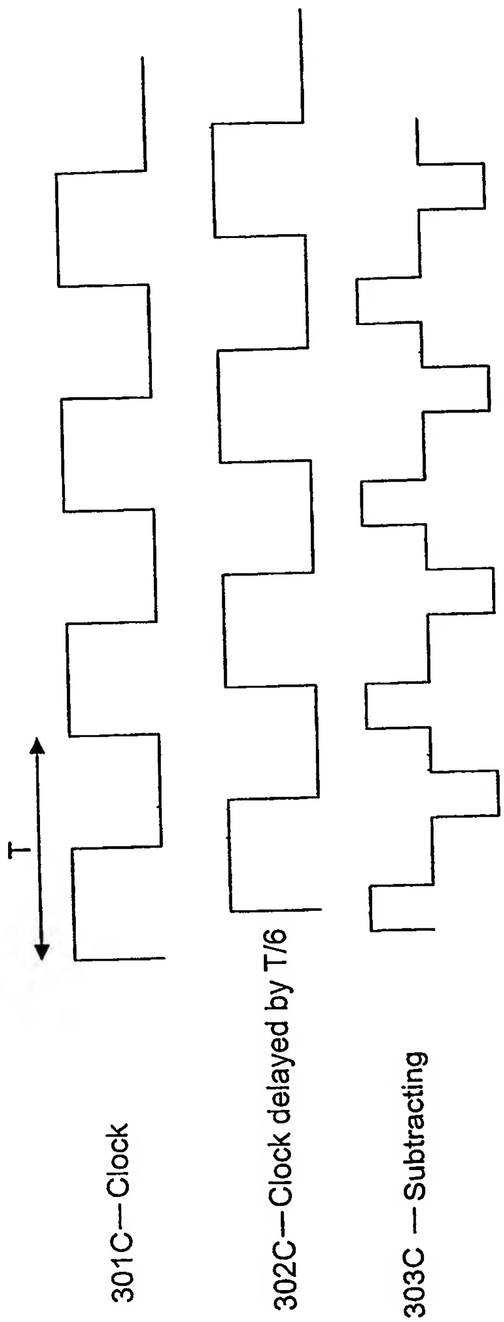
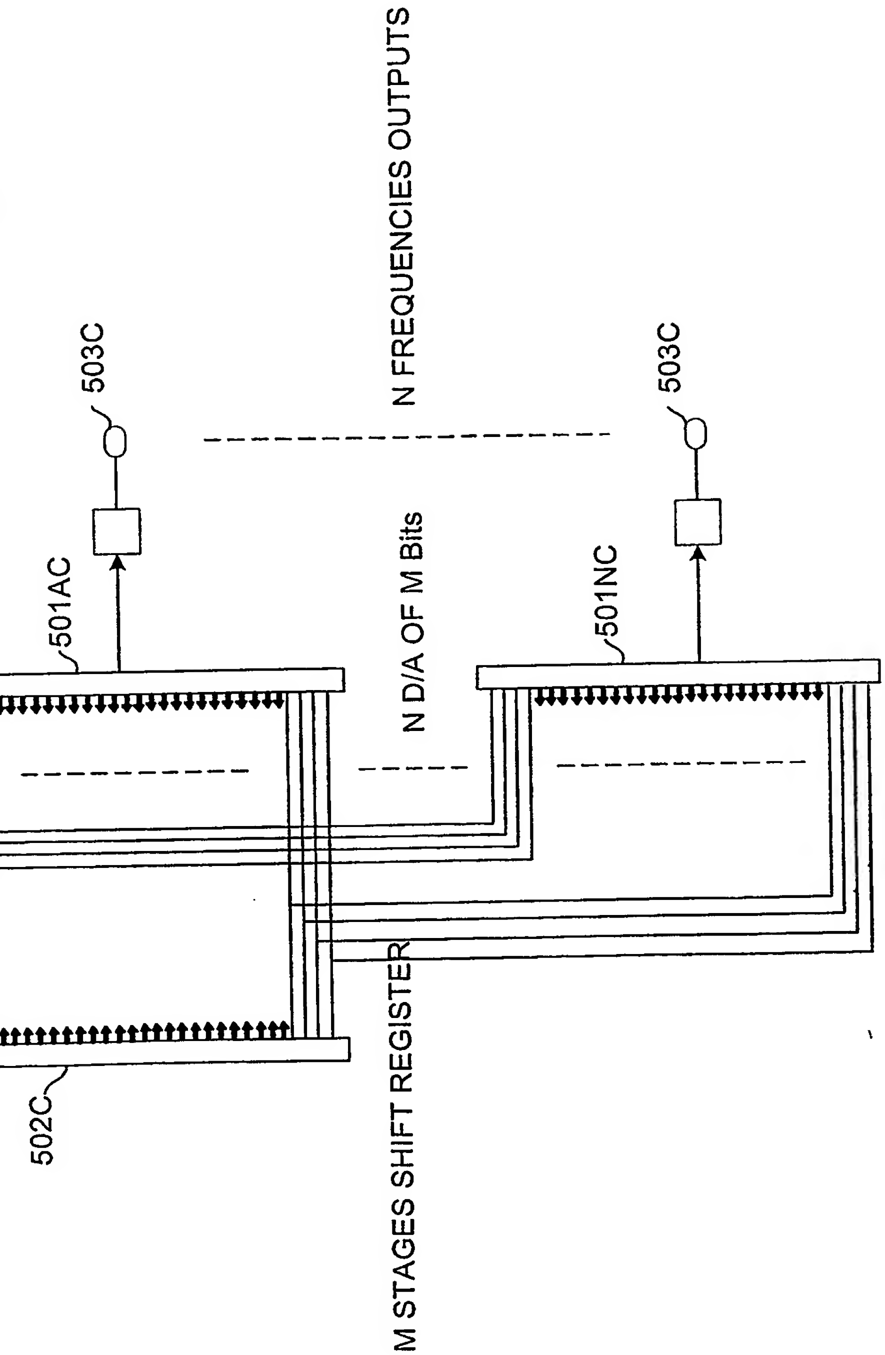


Figure 43

Carrier A	1A	2A	3A	4A	1A	2A	3A	4A	1A	2A	3A	4A
Carrier B	1B	2B	3B	4B	1B	2B	3B	4B	1B	2B	3B	4B
Carrier C	1C	2C	3C	4C	1C	2C	3C	4C	1C	2C	3C	4C
Multi Carrier	1A	2B	3C	4A	1B	2C	3A	4B	1C	2A	3B	4C

Figure 44

Figure 45


N FREQUENCIES OUTPUTS
503C
503C
501AC
501NC
N D/A OF M Bits
502C
M STAGES SHIFT REGISTER

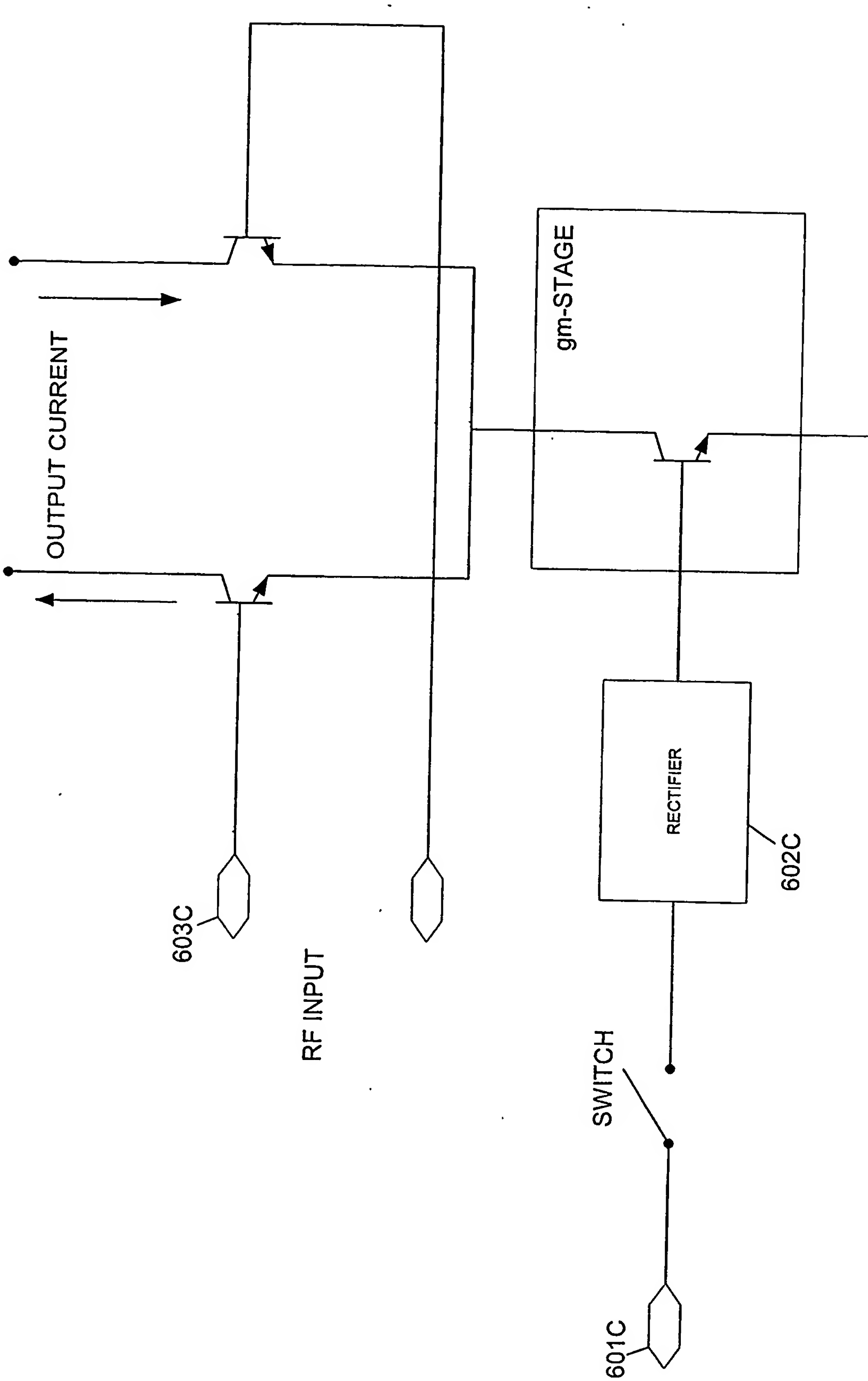
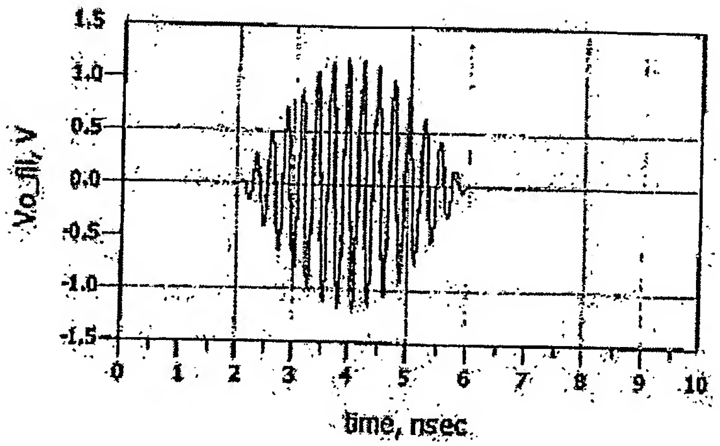

OUTPUT CURRENT
gm-STAGE
RECTIFIER
602C
603C
RF INPUT
SWITCH
601C

Figure 46

Figure 47A



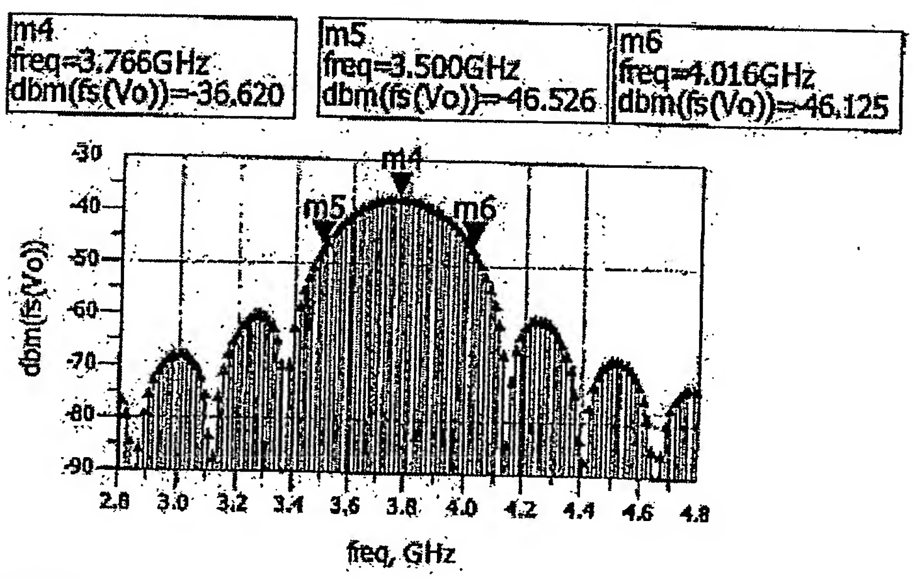


Figure 47B

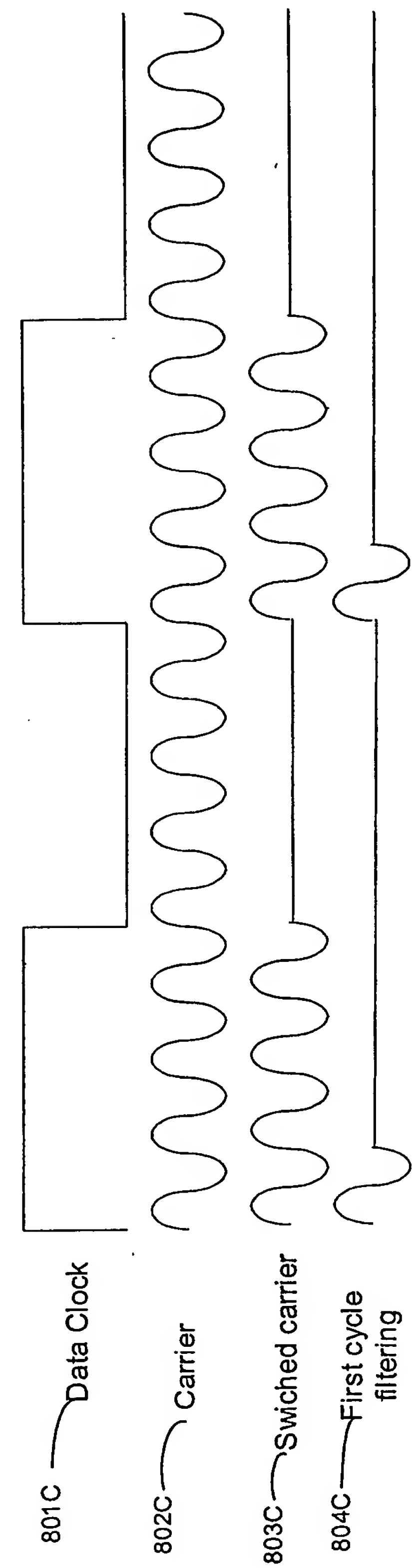

801C
Data Clock
802C
Carrier
803C
Swiched carrier
804C
First cycle filtering

Fig. 48

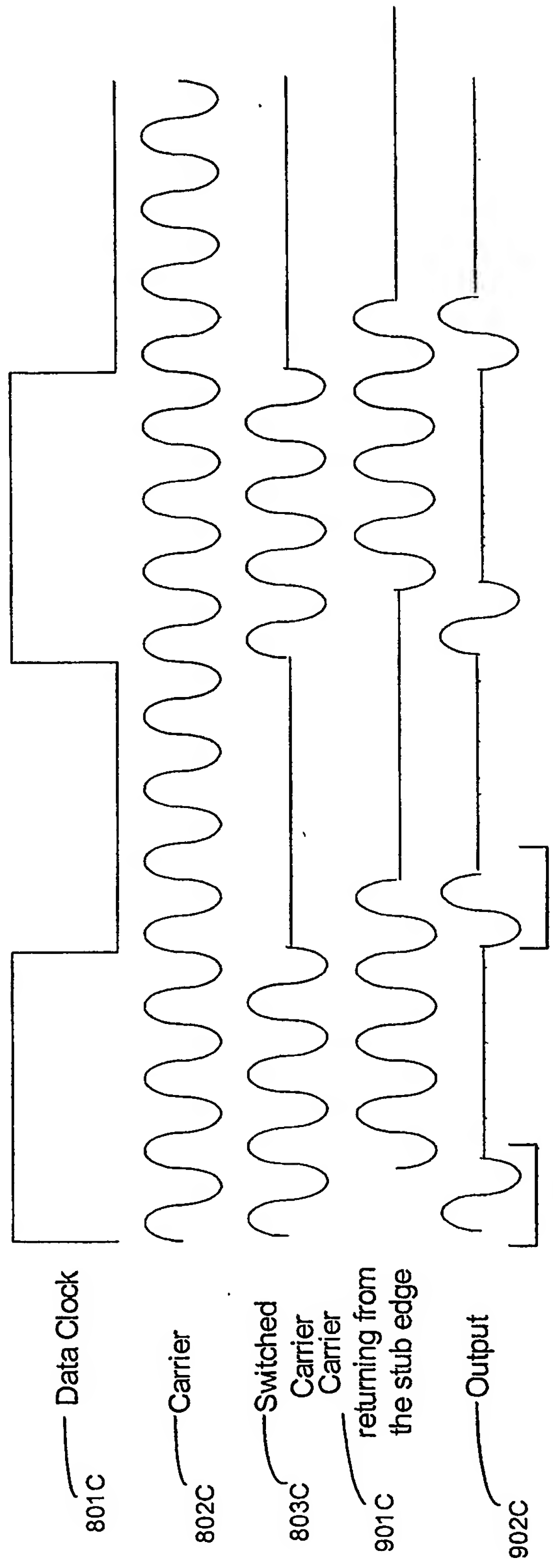

801C
Data Clock
802C
Carrier
803C
Switched Carrier
901C
Carrier returning from the stub edge
902C
Output
903
904

Figure 49

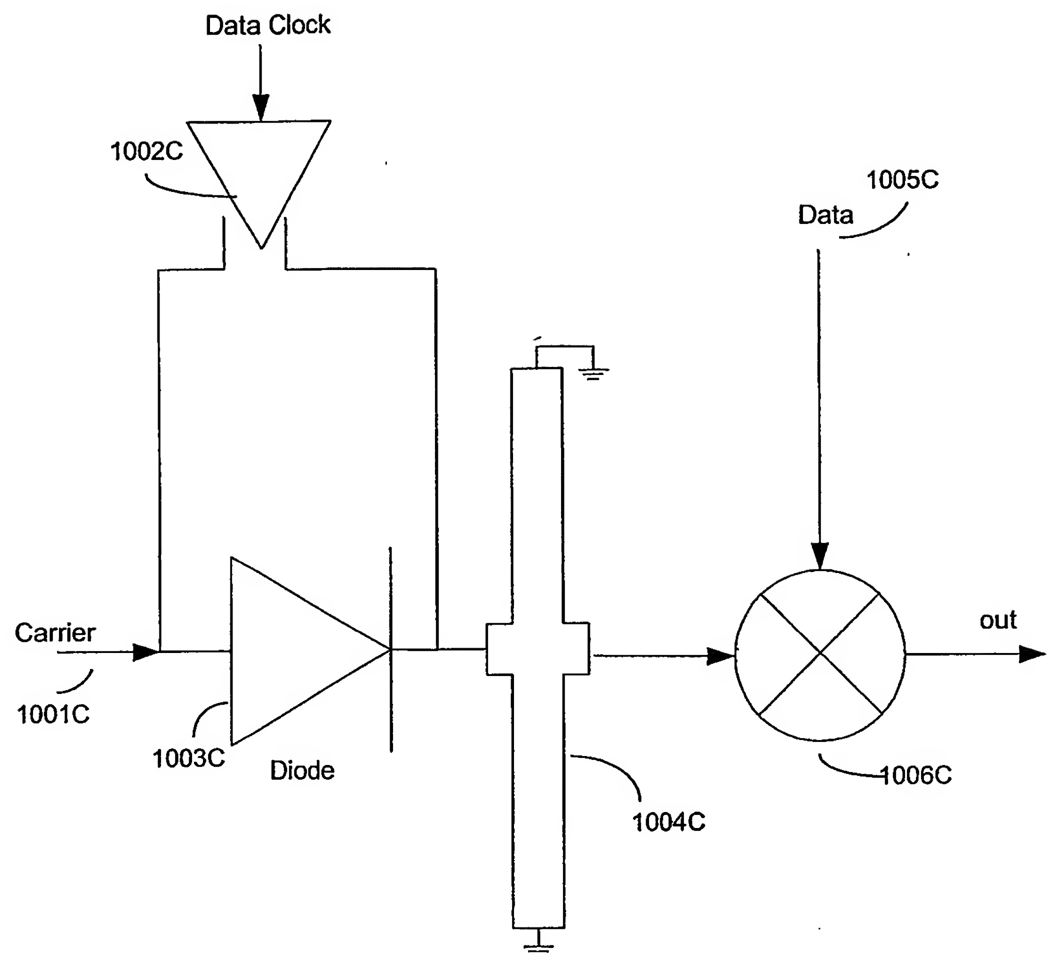

Data Clock
1002C
1005C
Data
Carrier
1001C
1003C
Diode
1004C
out
1006C

Figure 50

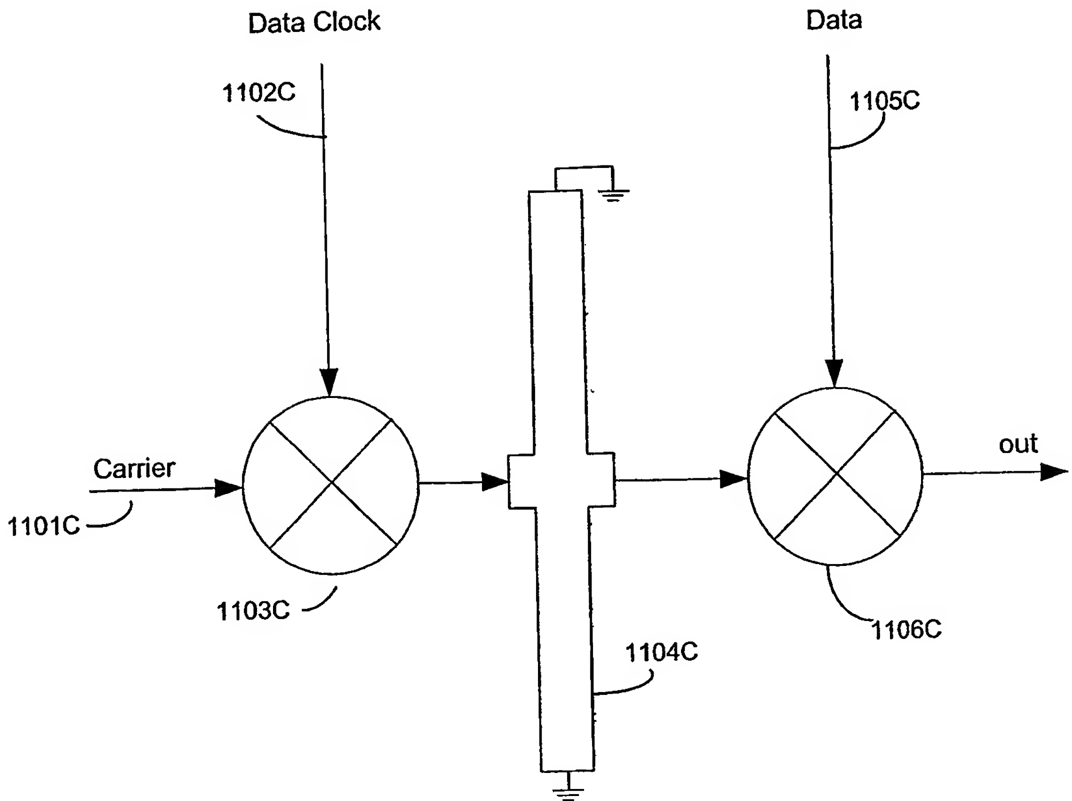

Data Clock
Data
1102C
1105C
Carrier
1101C
out
1103C
1106C
1104C

Fig. 51

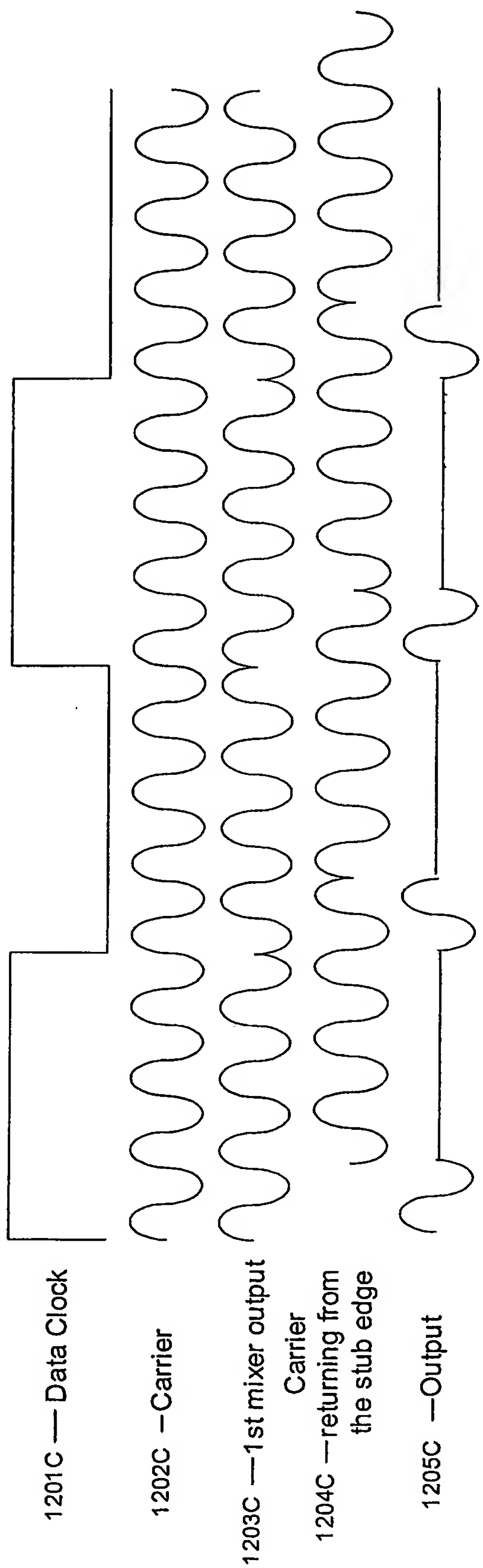

1201C —Data Clock
1202C —Carrier
1203C —1st mixer output
1204C —Carrier returning from the stub edge
1205C —Output

Figure 52

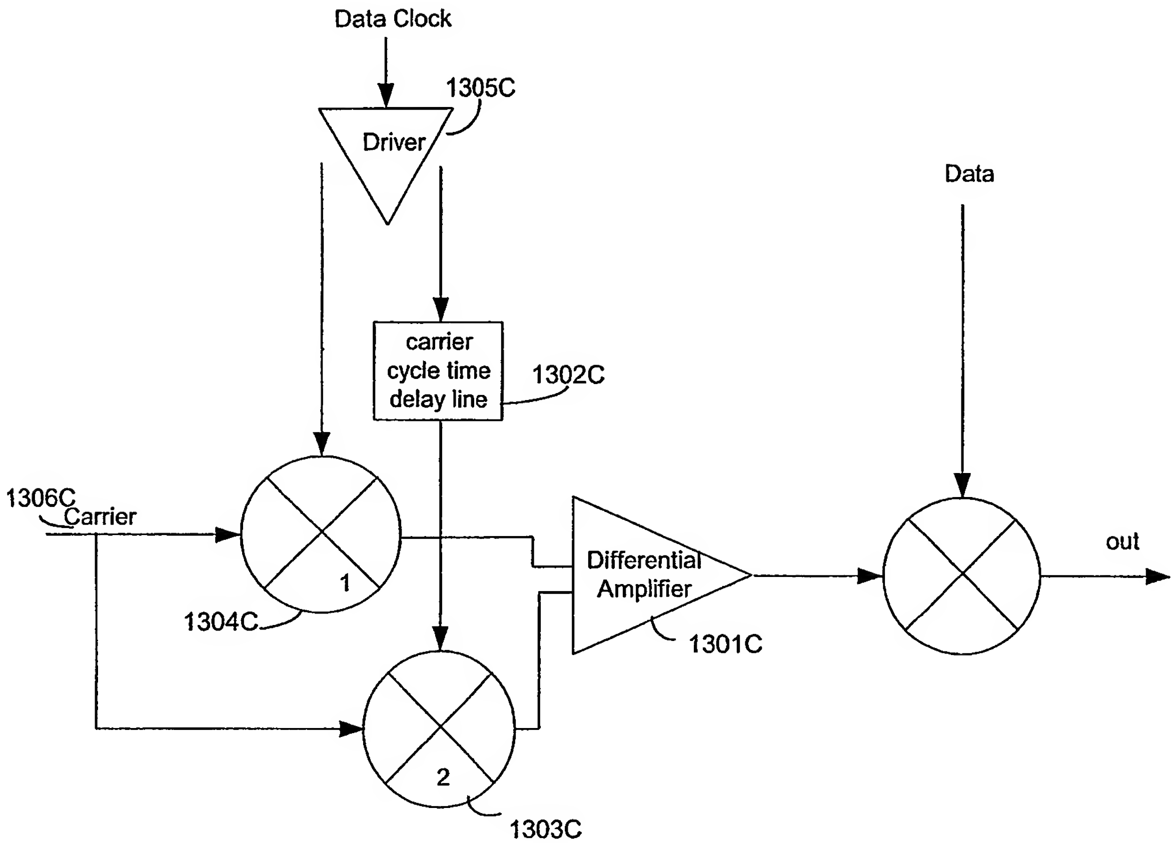

Data Clock
1305C
Driver
Data
carrier
cycle time
delay line
1302C
1306C
Carrier
1
1304C
Differential
Amplifier
1301C
out
2
1303C

Figure 53

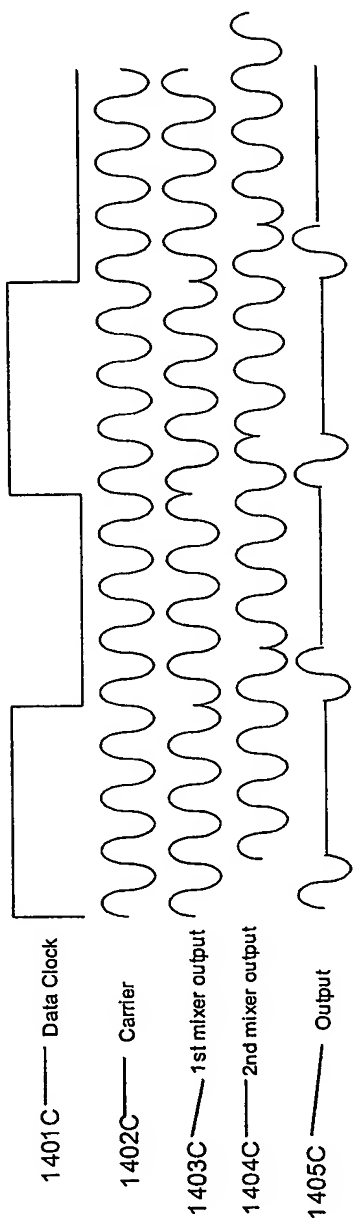

1401C Data Clock
1402C Carrier
1403C 1st mixer output
1404C 2nd mixer output
1405C Output

Figure 54

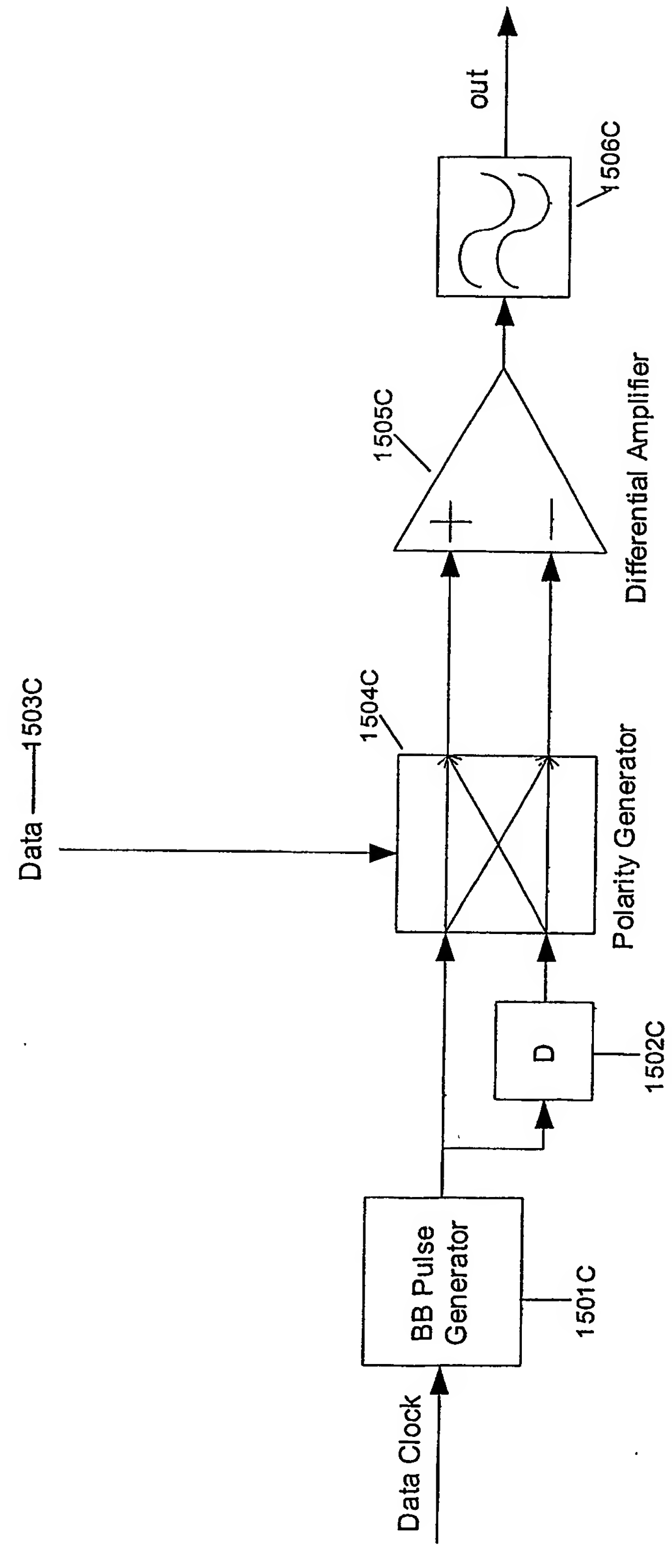

Data Clock
BB Pulse Generator
1501C
D
1502C
Data
1503C
1504C
Polarity Generator
1505C
Differential Amplifier
1506C
out

Figure 55

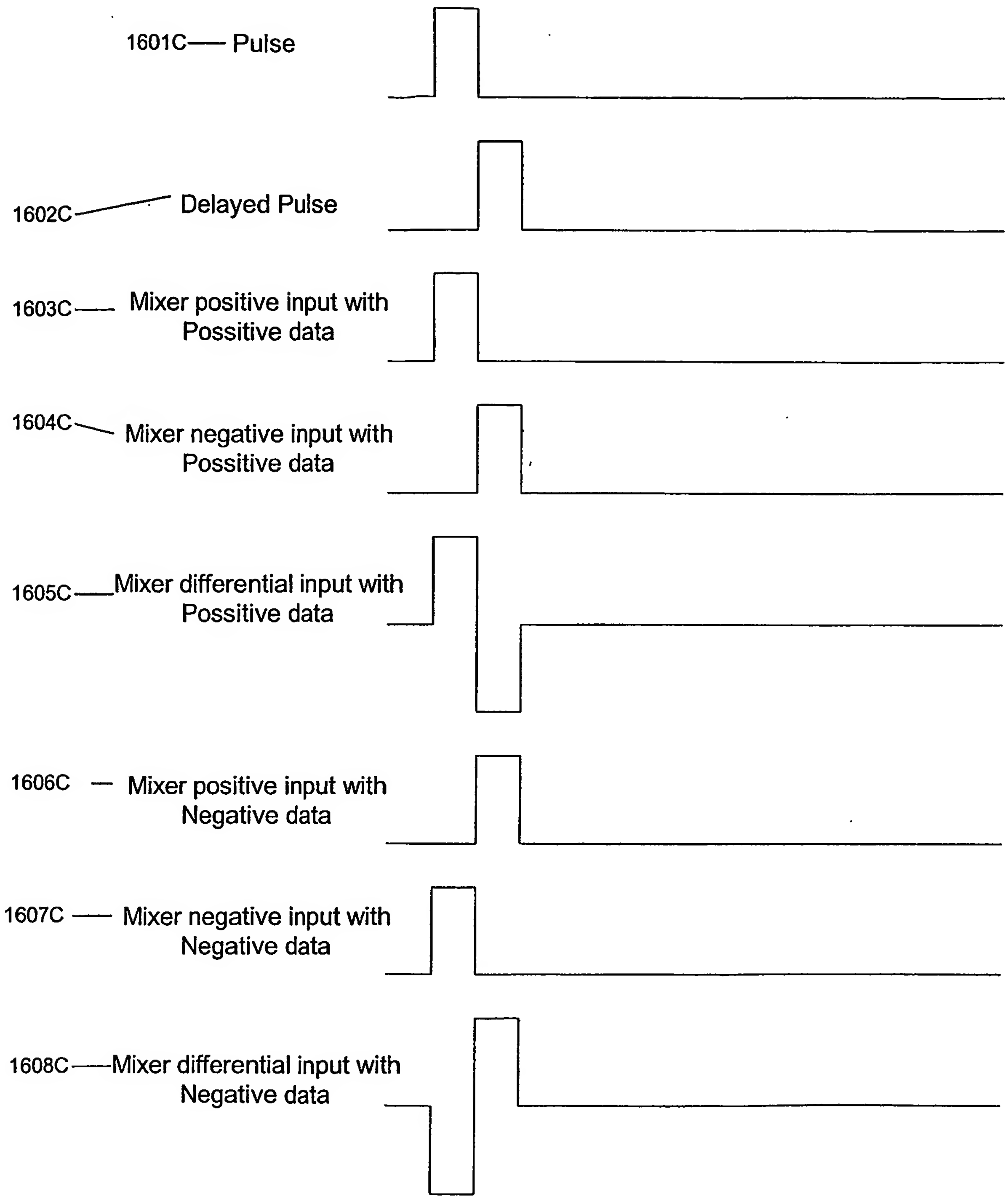

1601C Pulse
1602C Delayed Pulse
1603C Mixer positive input with Possitive data
1604C Mixer negative input with Possitive data
1605C Mixer differential input with Possitive data
1606C Mixer positive input with Negative data
1607C Mixer negative input with Negative data
1608C Mixer differential input with Negative data

Figure 56

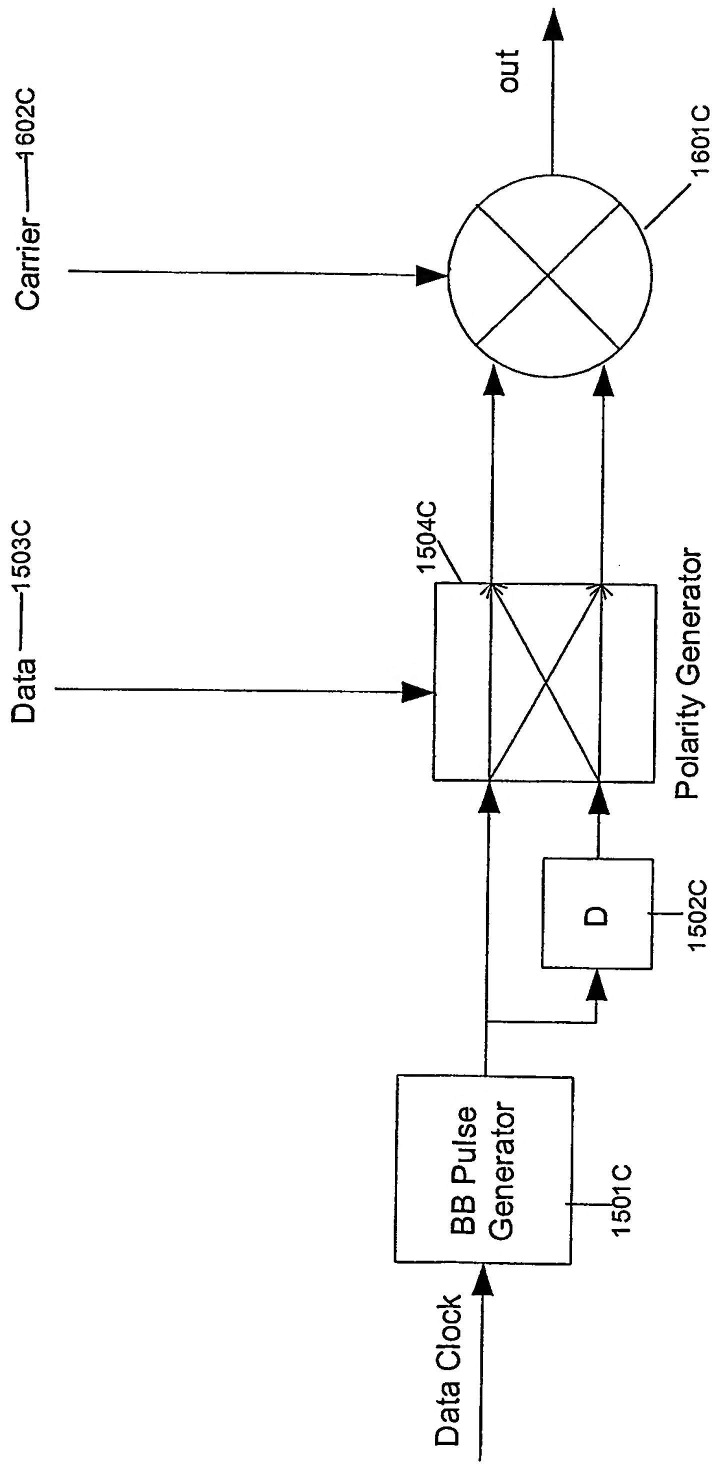

Carrier
1602C
out
1601C
Data
1503C
1504C
Polarity Generator
D
1502C
BB Pulse Generator
1501C
Data Clock

Figure 57

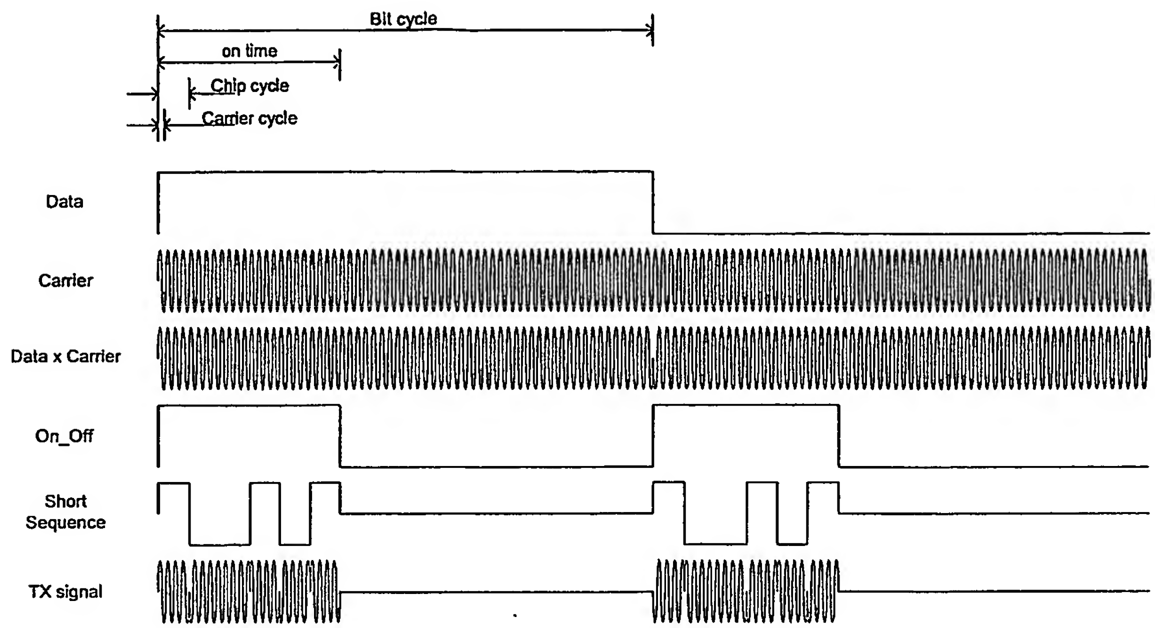

Bit cycle
on time
Chip cycle
Carrier cycle
Data
Carrier
Data x Carrier
On_Off
Short Sequence
TX signal

Figure 58

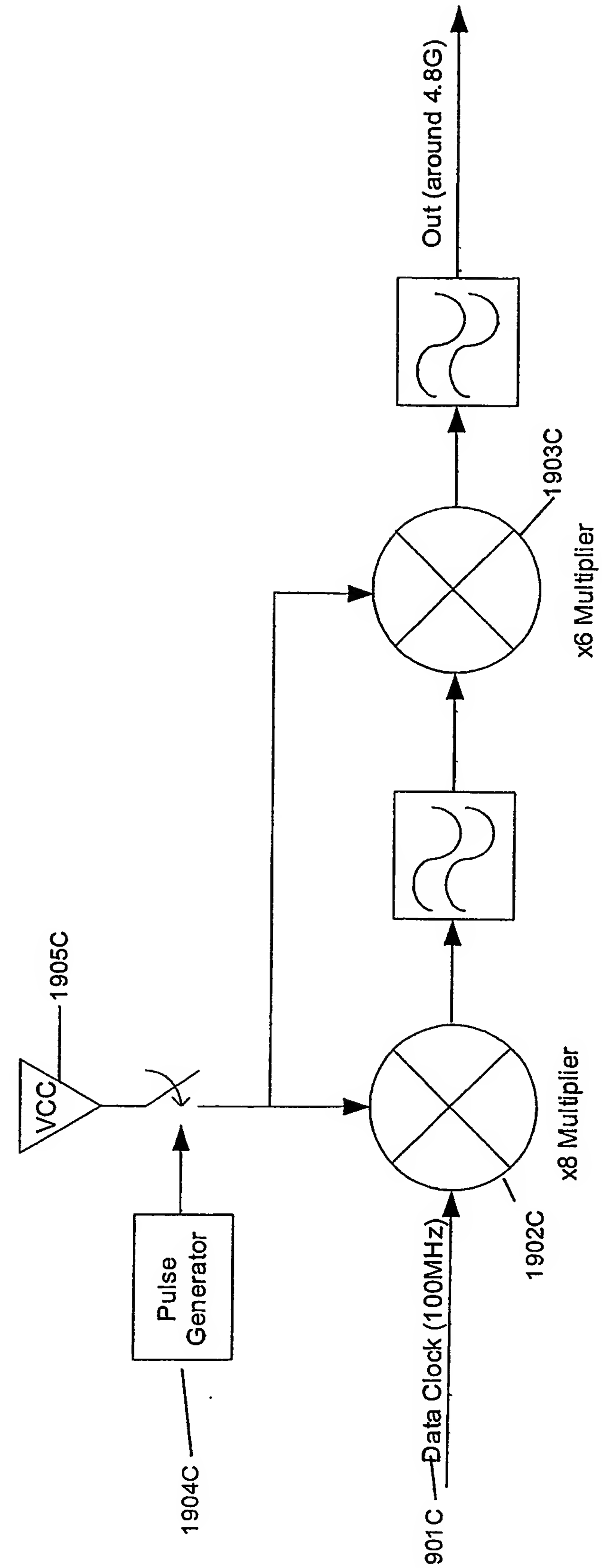

Out (around 4.8G)
1903C
x6 Multiplier
1905C
VCC
Pulse Generator
x8 Multiplier
1902C
Data Clock (100MHz)
1904C
1901C

Figure 59

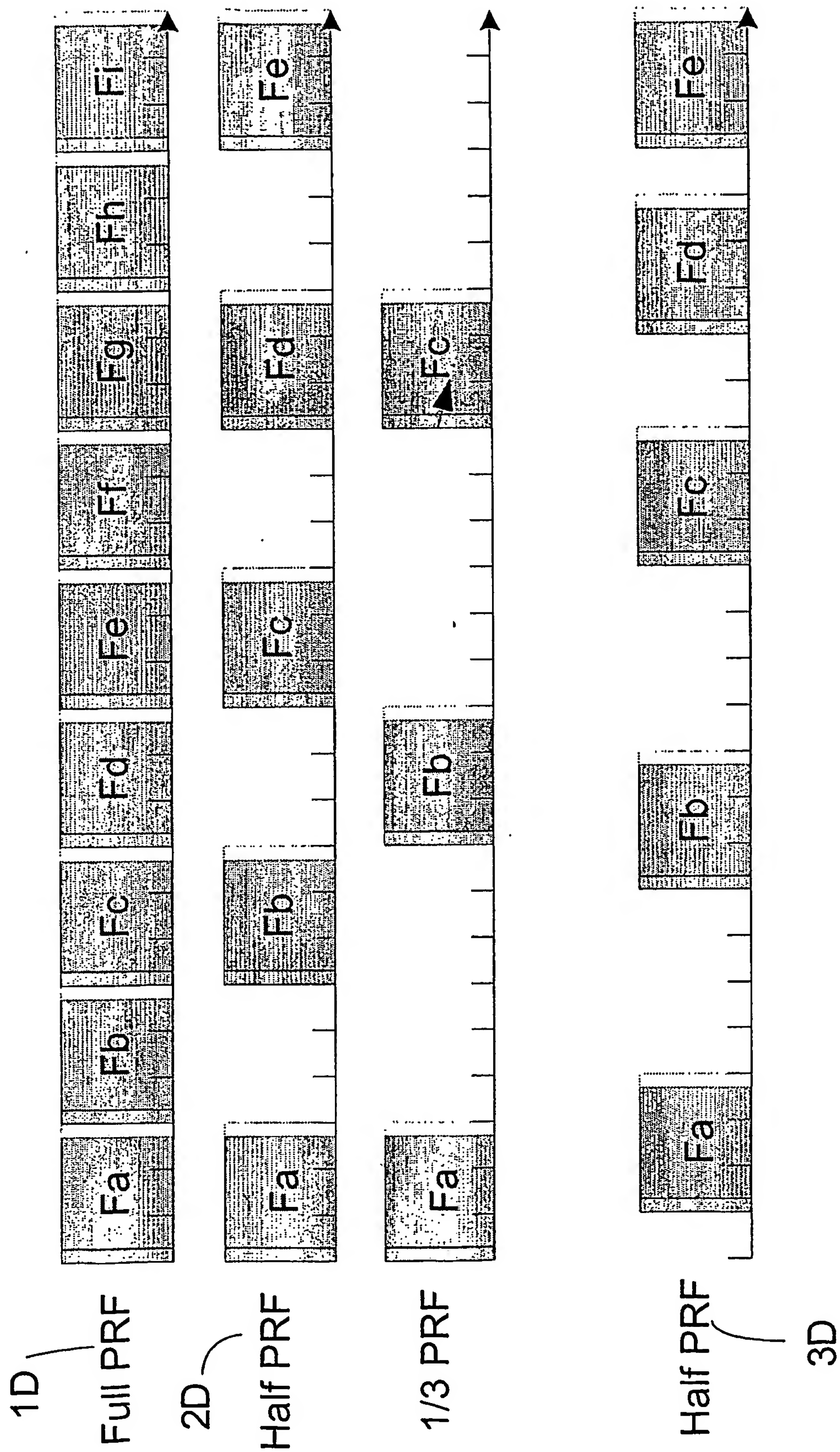

1D
Full PRF
Fa
Fb
Fc
Fd
Fe
Ff
Fg
Fh
Fi
2D
Half PRF
Fa
Fb
Fc
Fd
Fe
1/3 PRF
Fa
Fb
Fc
Half PRF
3D
Fa
Fb
Fc
Fd
Fe

Figure 60

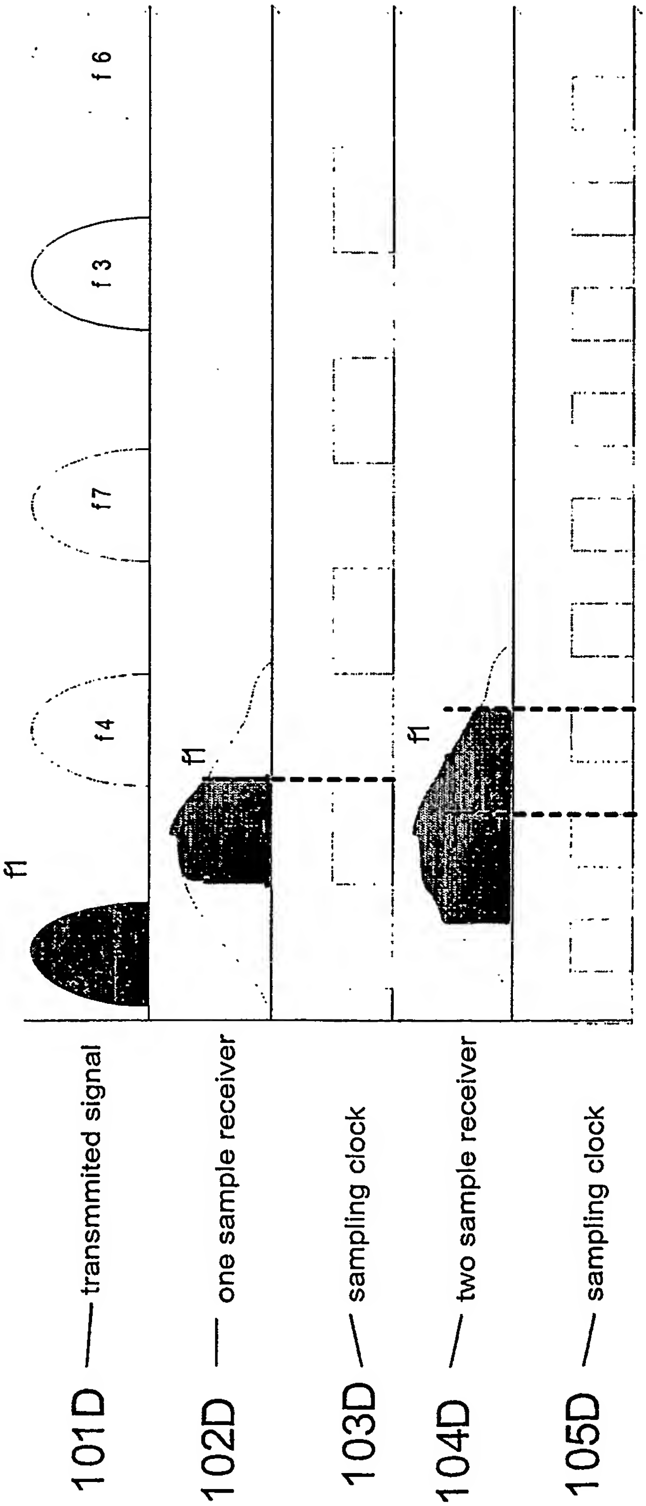

101D transmmited signal
102D one sample receiver
103D sampling clock
104D two sample receiver
105D sampling clock
f1
f4
f7
f3
f6
f1
f1

Figure 61

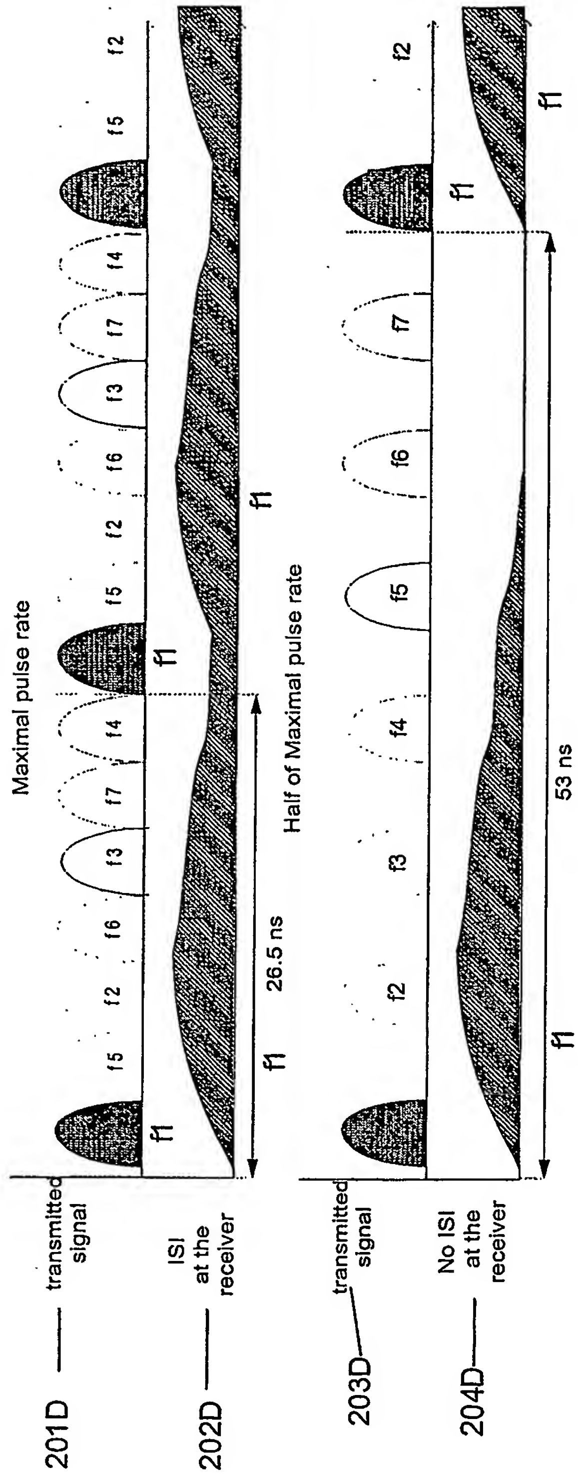

201D
transmitted signal
202D
ISI at the receiver
203D
transmitted signal
204D
No ISI at the receiver
Maximal pulse rate
Half of Maximal pulse rate
26.5 ns
53 ns
f1
f2
f3
f4
f5
f6
f7

Figure 62

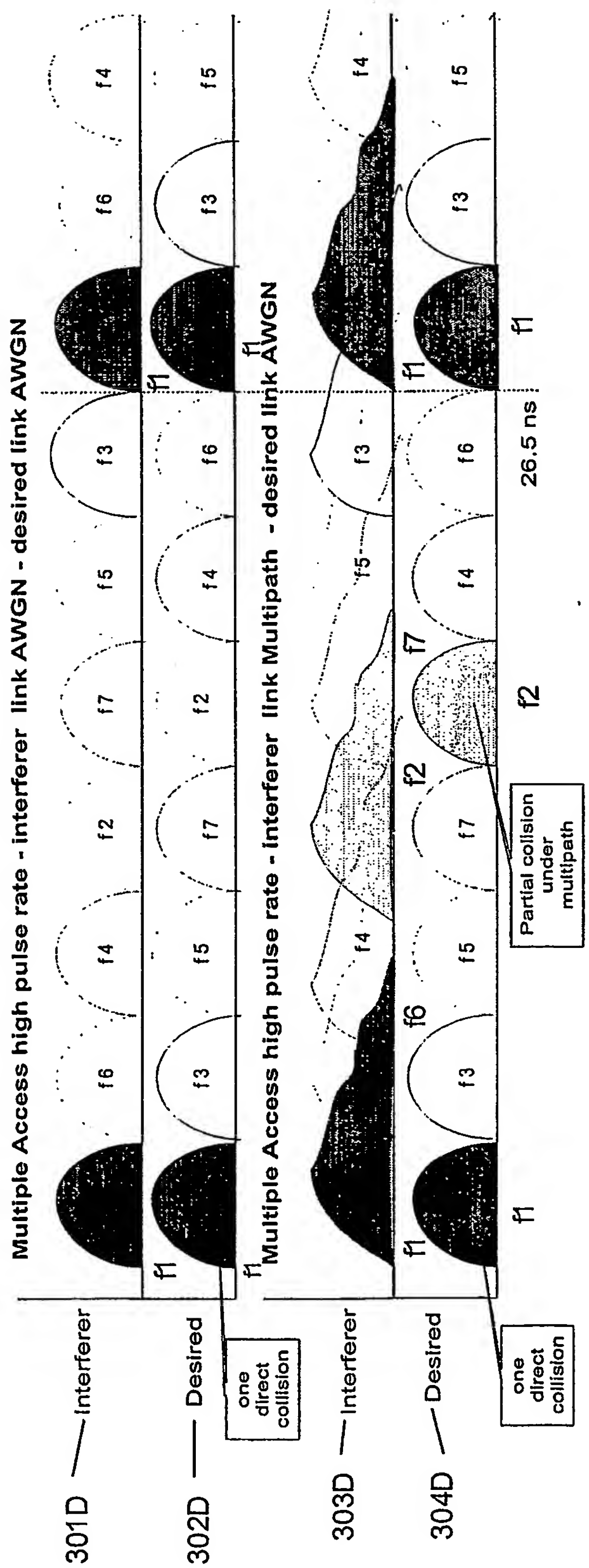

Multiple Access high pulse rate - interferer link AWGN - desired link AWGN
Multiple Access high pulse rate - interferer link Multipath - desired link AWGN
301D
Interferer
302D
Desired
303D
Interferer
304D
Desired
one direct collision
one direct collision
Partial collision under multipath
26.5 ns
f1
f2
f3
f4
f5
f6
f7

Fig. 63

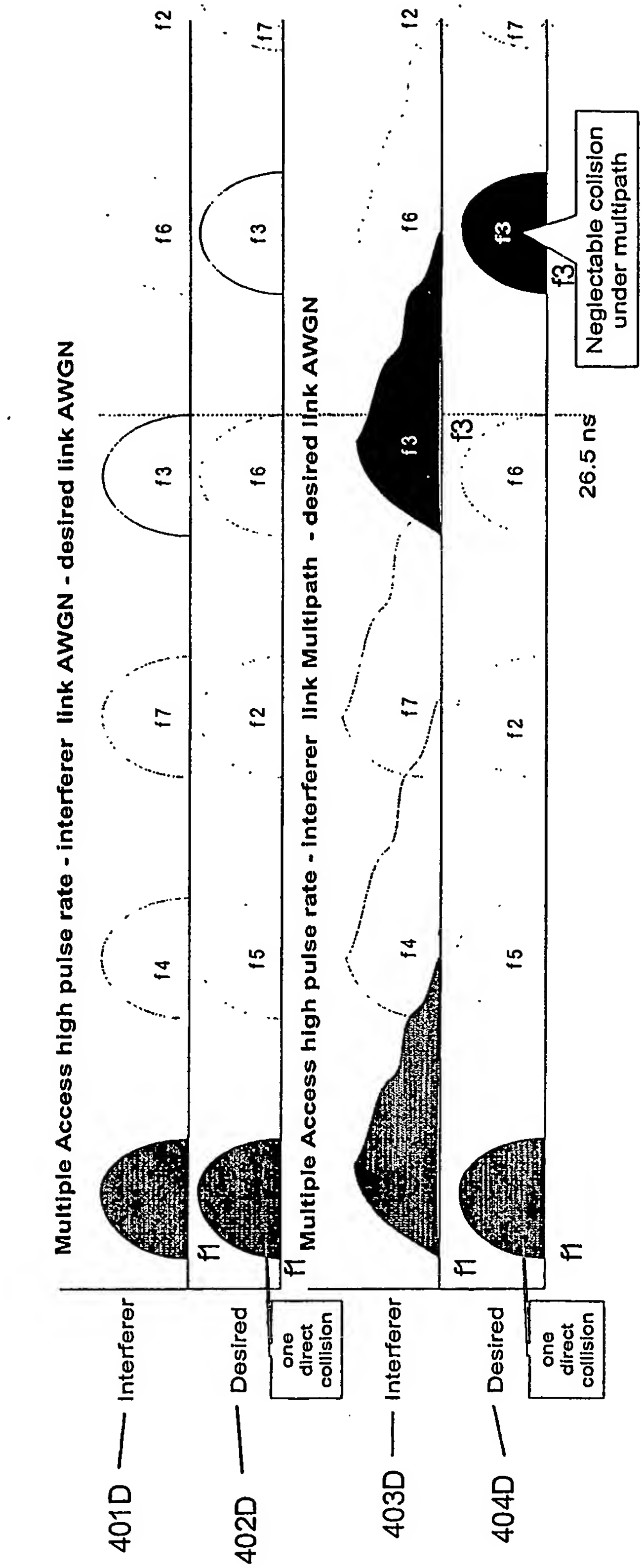

Multiple Access high pulse rate - interferer link AWGN - desired link AWGN
Multiple Access high pulse rate - interferer link Multipath - desired link AWGN
401D
Interferer
402D
Desired
one direct collision
403D
Interferer
404D
Desired
one direct collision
f1
f4
f7
f3
f6
f2
f5
f2
f6
f3
f7
26.5 ns
Neglectable colision under multipath

Figure 64

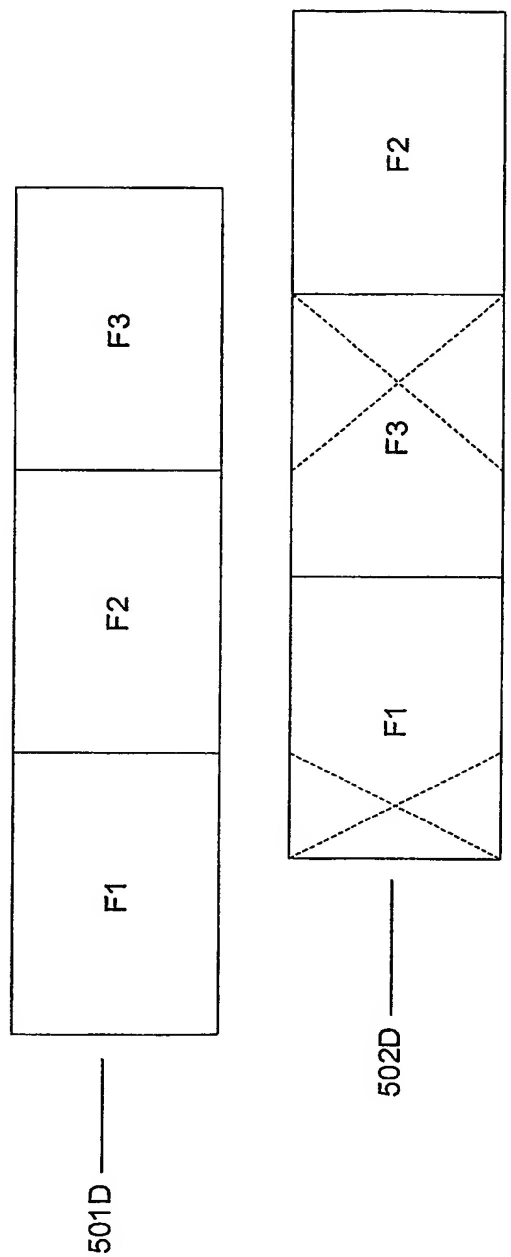


Figure 65

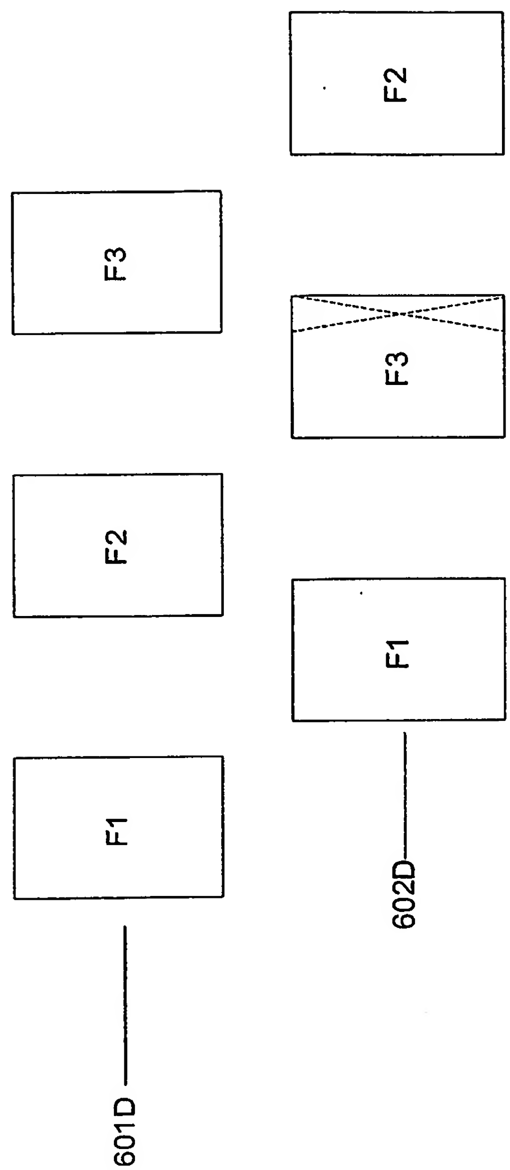


Figure 66

S1	1	2	3	4	5	6	7
S2	1	3	5	7	2	4	6
S3	1	4	7	3	6	2	5
S4	1	5	2	6	3	7	4
S5	1	6	4	2	7	5	3
S6	1	7	6	5	4	3	2

Figure 67

Full Rate	1	3	5	7	2	4	6	1	3	5	7	2	4	6	1	3	5	7	2	4	6
Half Rate	1		5		2		6		3		7		4		1		5		2		6
Low Rate	1			7			6			5			4			3			2		

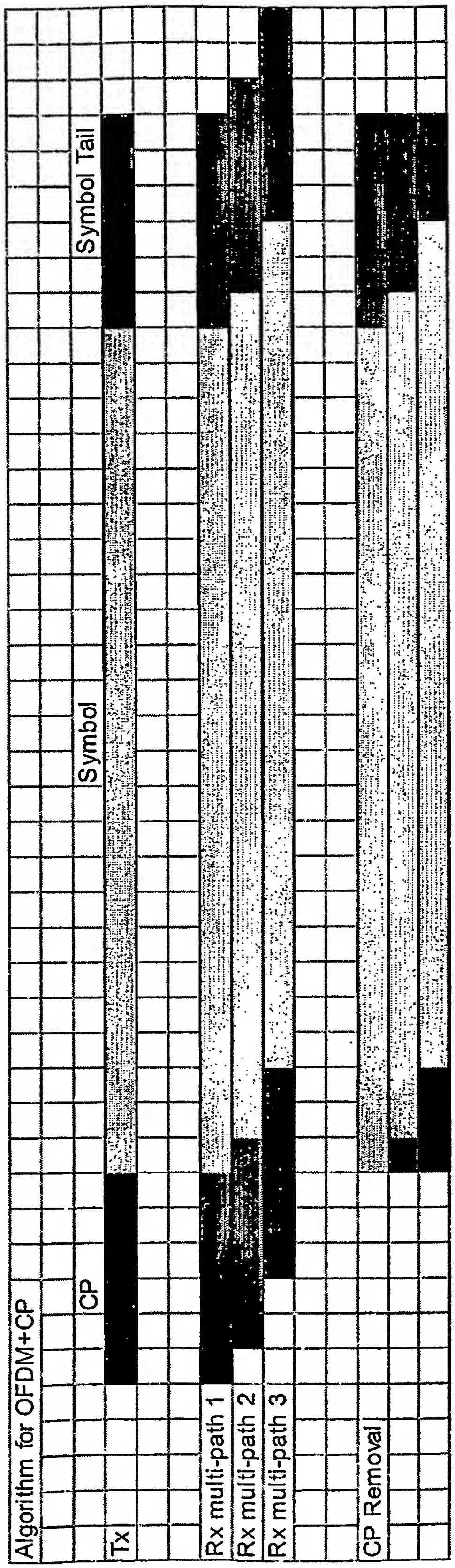
Figure 68

Full Rate	1	3			2	4		1	3			2	4		1	3			2	4	
Half Rate	1				2				3				4		1				2		
Low Rate	1												4			3			2		

Figure 69

Parallel Transmission	Upper Band	8	10	12	14	9	11	3	8	10	12	14	9	11	3	8	10	12	14	9	11	3
	Lower Band	1	3	5	7	2	4	6	1	3	5	7	2	4	6	1	3	5	7	2	4	6

Figure 70


Algorithm for OFDM+CP
CP
Symbol
Symbol Tail
Tx
Rx multi-path 1
Rx multi-path 2
Rx multi-path 3
CP Removal

Figue 71

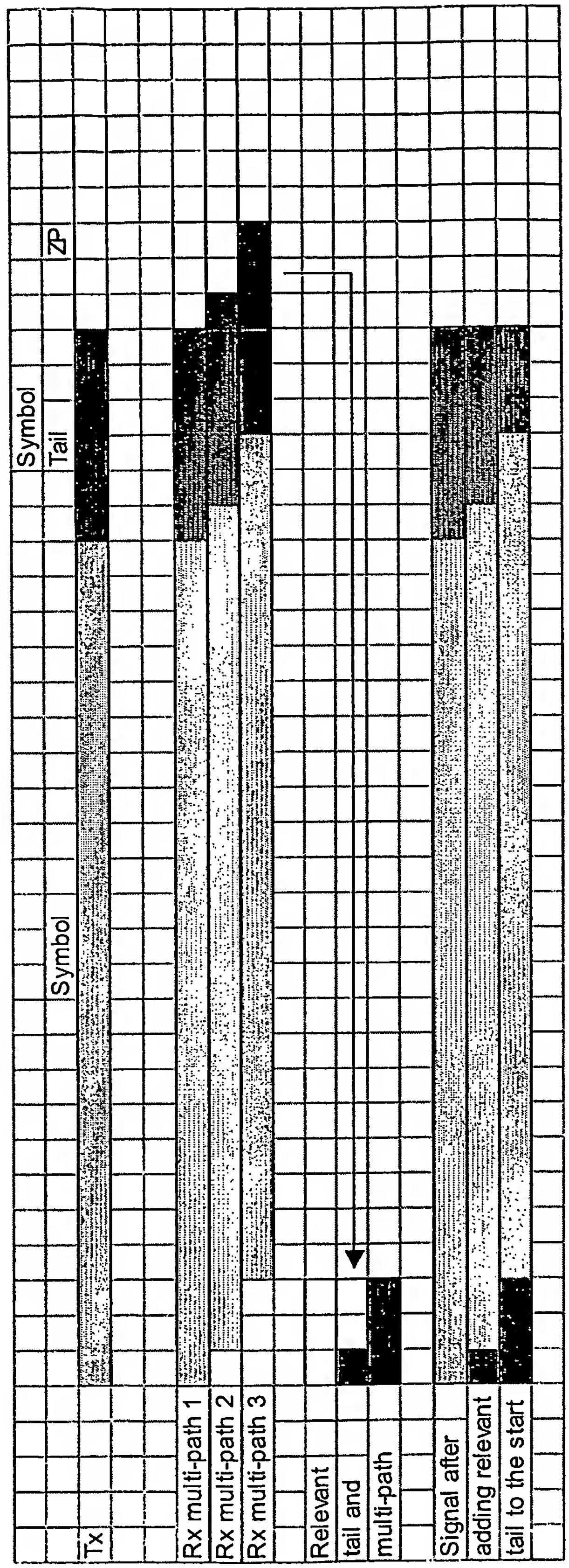

Symbol
Tail
ZP
Symbol
Tx
Rx multi-path 1
Rx multi-path 2
Rx multi-path 3
Relevant
tail and
multi-path
Signal after
adding relevant
tail to the start

Figure 72

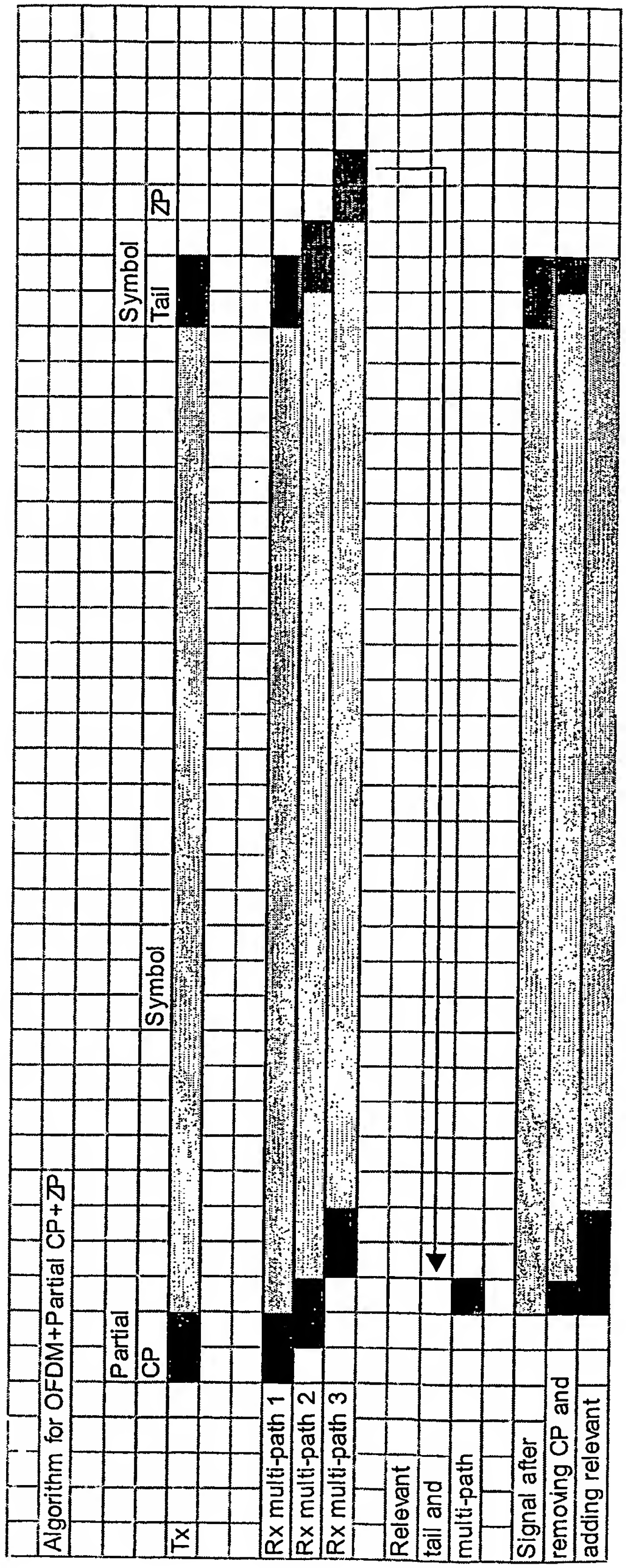

Algorithm for OFDM+Partial CP+ZP
Partial
CP
Symbol
Symbol
Tail
ZP
Tx
Rx multi-path 1
Rx multi-path 2
Rx multi-path 3
Relevant
tail and
multi-path
Signal after
removing CP and
adding relevant

Figure 73